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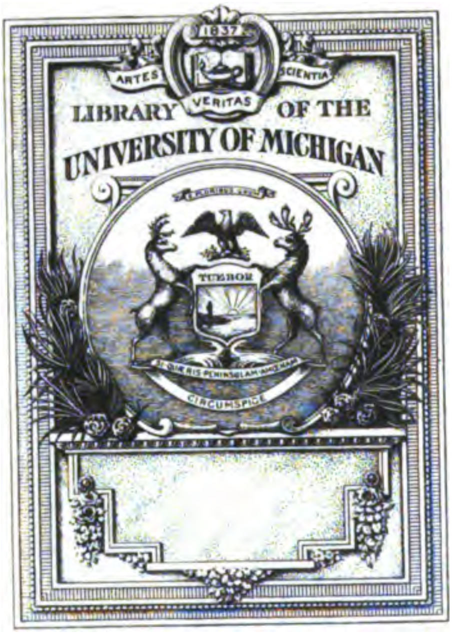

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IN COMMEMORATION OF THE WORK OF
THE EIGHT THOUSAND YALE MEN
WHO TOOK PART IN THE WORLD WAR
1914-1918

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HOW AMERICA WENT TO WAR

THE GIANT HAND
THE ROAD TO FRANCE I.
THE ROAD TO FRANCE II.
THE ARMIES OF INDUSTRY I.
THE ARMIES OF INDUSTRY II.
DEMOBILIZATION

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Crowell, Benedict, 1869-

HOW AMERICA WENT TO WAR

AN ACCOUNT FROM OFFICIAL SOURCES OF THE NATION'S WAR ACTIVITIES

1917-1920

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A Gas Attack

From a photograph by the Signal Corps

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THE
ARMIES OF INDUSTRY

II.

OUR NATION'S MANUFACTURE OF MUNITIONS FOR A WORLD IN ARMS
1917-1918

BY BENEDICT CROWELL
THE ASSISTANT SECRETARY OF WAR AND
DIRECTOR OF MUNITIONS 1917-1920

AND ROBERT FORREST WILSON
FORMERLY CAPTAIN, UNITED STATES ARMY

ILLUSTRATED WITH PHOTOGRAPHS FROM THE COLLECTIONS OF THE WAR AND NAVY DEPARTMENTS

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CHAPTER XIX

OTHER AIRPLANE ENGINES

THE production of the Liberty engine so captured popular attention that the public never fairly understood or appreciated the extent of another production enterprise on the part of those who provided motive power for our war airplanes. This was the supplementary manufacture of aëro engines other than those which bore the proud appellation of "Liberty."

Let the production figures speak for themselves. In those nineteen months, starting with nothing, we turned out, complete and ready for service, 32,420 aëro engines. Of these thousands of engines, less than one-half—the exact figure being 15,572—were Liberty engines. The rest were Hispano-Suizas, Le Rhones, Gnomes, Curtisses, Hall-Scotts, and some others, a total of 16,848 in all—built largely for the training of our army of the air. This production would have been even more notable had the war continued, for at the date of the signing of the armistice the United States had contracted for the construction of 100,993 aircraft engines. Of these, 64,100 were to have been Liberty engines; so that the total plan of construction of engines other than the Liberty would have produced about 37,000 of them. The total cost of carrying through the combined engine project would have been in the neighborhood of $450,000,000.

At the outbreak of the war American knowledge of military aviation may have been meager; still, it was evident from the start that we should be able to go ahead with certain phases of production on a huge scale without waiting for the precise knowledge of requirements that would come only from an exhaustive study of the subject in Europe. In the first place,

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we knew that we must train our aviators. For this purpose there was at the start no particular need of the highly developed machinery then in use on the western front. The first aircraft requirements of the early training program were safe planes, regardless of type, and motive power to drive them. Later on, when we were better prepared, would come the training that would afford our aviators experience with the fighting equipment. At the start there was no reason why we should not proceed at once with the construction of such training machines as we knew how to build.

An aviation program for war falls into these two divisions—the equipment required for training and that required for combat. While our organization, particularly through the Bolling commission which we had sent to Europe, was making a study of our combat requirements, and while we were pushing forward the design and production of the Liberty engine, we forthwith developed on an ambitious scale the manufacture of training planes and engines in this country. The training of battle aviators likewise falls into two parts, the elementary training and the advanced. The elementary training merely teaches the cadet the new art of maintaining himself in the air. Later, when he has mastered the rudiments of mechanical flight, he goes into the advanced training, the training in his fighting plane, where he requires equipment more nearly of the type used at the front.

For the elementary training we had some good native material to start with. The Curtiss Aeroplane & Motor Corporation had been building training planes and engines for both the English and the Canadian air authorities. Its product was evidently the most available American airplane for our first needs. The Curtiss plane was known as the "JN-4," and it was driven by a 90-horsepower engine called the Curtiss "OX." In the production of this equipment on the scale planned by the Signal Corps, the embarrassing feature, the choke point, was evidently to be the manufacture of the engine. The Curtiss plant at Buffalo for the manufacture of planes could be quickly expanded to meet the government demands; but the

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Curtiss engine plant at Hammondsport, New York, could not develop the production of "OX" engines up to our needs and at the same time complete the orders which it was filling for the English and Canadian air services. Therefore contracts were awarded to the Curtiss Company for its capacity in the production of "OX" engines, and then the American aviation authorities came to an agreement with the Willys-Morrow plant at Elmira, New York, for an additional 5,000 of these motors. Ordinarily it would require from five to six months to equip a plant with the large machine tools and the smaller mechanical appliances necessary for such a contract as this. But the Willys-Morrow plant tooled up in three months and was ready to start on the "OX" manufacturing job.

If speed in production was required at any point in the aviation development, it was here in the manufacture of the elementary training planes and engines. Without training material, no matter how many aviation fields we set in order or how many student aviators we enlisted, the movement of our flying forces toward the front could not even begin. And here entered an interesting engineering and executive problem that had to be worked out quickly by those in charge of our aircraft construction. The curve of requirements for aircraft training material, if it were plotted on paper, would climb swiftly to its peak during the first six or eight months of the war and then decline with almost equal swiftness until it reached a low level. In other words, we must produce the great number of training machines in the shortest time possible, in order to put our thousands of student aviators into the air at once over the training fields; but when this training equipment had been brought up to initial requirements, thereafter our needs in this direction would be met by only a small production, for the rate of wastage of such material is relatively low. Once our fields were fully equipped, the same apparatus could be used over and over again as the war went on, with little regard to the improvements of the type of battle planes; so that the ultimate manufacture need be large enough only to keep this equipment in condition.

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It soon became evident that the production of Curtiss planes and engines, even under the heavy contracts immediately placed, would not be sufficient to take care of our elementary training needs; and the aviation administration began looking around for other types of aircraft that would fit into our plans. The experts in all branches of war flying whom the principal Allied nations had sent to the United States warned us against the temptation to adopt many types of *matériel* in order to secure a quick early production. If the training equipment were not closely standardized in types, it would result in confusion and delay, both in training the aviator to fly and in preparing him for actual combat. Such had been the experience in Europe; and we were now given the benefit of this experience, so that we might avoid the mistakes which others had made. We were advised to adopt a single type of equipment for each class of training; but if that were not consistent with the demand for speed in getting our service into the air, then at the most we should not have more than two types of either planes or engines.

In the elementary training program it was evident, as a matter of fact, that we could not equip ourselves with a single type of plane except at considerable expense in time. Consequently we went ahead to develop another. We found a training airplane, produced by the Standard Aero Corporation, known as the "Standard-J." The company had been developing this machine for approximately a year, and its plant could be expanded readily to meet a large contract. For the engine to drive this plane we adopted the Hall-Scott "A7A." This was a 4-cylinder engine. It had the fault of vibration common to all 4-cylinder engines, but it was regarded by experts as a rugged and dependable piece of machinery. The Hall-Scott Company was equipped to produce this motor on an extensive scale, for at the time this concern was probably the largest manufacturer of aviation engines in the United States, with the possible exception of the Curtiss Company. The engine had been used in airplanes built by the Standard Aero Corporation, the Aeromarine Company, and the Dayton-

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Wright Company. Therefore the Joint Army and Navy Technical Board recommended the Standard–J plane and the Hall-Scott "A7A" engine as the elementary training equipment to alternate with the Curtiss plane and engine. The Government placed contracts with the Hall-Scott Company for 1,250 engines, its capacity. But, since a large additional number would be required, a supplementary contract for 1,000 "A7A's" was given to the Nordyke & Marmon Company. The Hall-Scott Company coöperated with this latter concern by furnishing complete drawings, tools, and other production necessaries.

When it came to the advanced training for our aviators, more highly developed mechanical equipment was required. There must be two sorts of this equipment. The advanced student must become acquainted with rotary engines such as were used by the French and others to drive the small, speedy *chasse* planes; and he must also come to be familiar with the operation of fixed cylinder engines of upwards of 100 horsepower, such as were in commonest use on observation and bombing planes. For each type, the rotary and the fixed, we were permitted by our policy to have two sorts of engines, in order to get into production as quickly as possible, but not more than two.

Here again we had to survey the field of engine manufacture and choose exactingly, at the same time making, in point of speed, approximately as good a showing as if we had adopted every engine with claims to our consideration and had told manufacturers of them to produce as many as they could.

To cover the need of rotary engines, our aviation representatives in Europe advised the production here of Gnome and Le Rhone motors. There were two models of the Gnome engine, one developing 110 horsepower and the other 150. The Le Rhone engine produced 80 horsepower. The Bolling commission had recommended that the Gnome 150 be used in some of our combat planes. In the spring of 1917 we were producing a few Gnome 110-horsepower engines in this country. The General Vehicle Company had taken, at some time previously, a

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foreign order for these engines. But neither the Gnome 150 nor the Le Rhone 80 had been built in the United States, both having been developed and used exclusively in France. The first recommendations from our observers in France advised us to produce 5,000 of the more powerful Gnome 150's and 2,500 Le Rhone 80's.

The production of Gnome engines in this country forms a good illustration of the manner in which aircraft requirements at the front were constantly shifting because of the rapid evolution of the science of mechanical flight. Our officers did not hesitate to overrule their previous decisions, if such a course seemed to be justified, even at the cost of rendering useless great quantities of work already done and material already produced. This has been shown in connection with the Liberty engine. At the start we set out to build Liberty 8-cylinder engines on a large scale, only to discontinue this work before it was fairly started; but later on we again took up a Liberty 8-cylinder project on almost as great a scale as had been planned originally.

So with the production of the heavy 150-horsepower Gnome engine. Our European advisers were first of the opinion that we should go heavily into this production; and the equipment end of the Signal Corps projected a program of 5,000 of the large Gnome engines. Such a contract was entirely beyond the capacity of the General Vehicle Company, which had been building the lighter Gnomes; and the Government entered into negotiations with the General Motors Company and asked it to assume the greater burden of this undertaking. Under the pilotage of the aircraft authorities, an agreement was reached for the industrial combination of the General Motors Company and the General Vehicle Company. The former concern brought its vast resources and numerous factories into the consolidation; the latter furnished the only skilled knowledge and experience there was in the United States in the art of making rotary engines. This seemed to be a great step in our progress and an achievement in itself; but just as the undertaking of the construction of large Gnome

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engines was about to be started, events in Europe caused our observers there to revise their first judgment, and we received cabled instructions recommending that we discontinue the development of the Gnome 150. The entire program for Gnome 150's was canceled, and thereafter the General Vehicle Company, with its relatively small capacity, was called upon to produce as many of the small Gnome 110's as it could. As a matter of record, the production of these engines amounted to 280.

The Signal Corps found it difficult to induce manufacturers in this country to undertake the construction of foreign-designed engines at all. The plans and specifications of mechanical appliances furnished by foreign engineers and manufacturers are so different from ours that trouble is invariably experienced in attempts to use them here. Successful concerns in this country naturally hesitated to pick up contracts on which they might fail and thus tarnish their reputations. Our advisers in Europe were insistent that we should produce Le Rhone engines in quantity in the United States; yet it was hard to find any manufacturing concern willing to undertake such a development. Nevertheless, the production of Le Rhone engines proved to be one of the most successful phases of the whole aircraft program. Its story illustrates the obstacles encountered in adapting a foreign device to American manufacture, and it also shows how American production genius can overcome these handicaps.

It was only after strenuous efforts on our part that the Union Switch & Signal Company, of Swissvale, Pennsylvania, a member of the Westinghouse chain of factories, was induced to take up the Le Rhone contract. This project called for the production of 2,500 rotary Le Rhones of 80 horsepower each. Let us see how the manufacturers took this totally unfamiliar machine and proceeded to reproduce it in this country.

One might think that it would be necessary only to take the French drawings, change the metric system measurements to our own scale of feet and inches, and proceed to turn out the mechanism. But it was not so simple as that. We did receive

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the drawings, the specifications, the metallurgical instructions, and the like; but these we found to be, from our point of view, unreliable and unsatisfactory. For instance, according to the French instructions the metallurgical requirements for the engine crank shaft called for mild steel. This was obviously incorrect; and if an error had crept into this part of the plans, there was no telling how faulty the rest of them might be. So, from the metallurgical standpoint alone, this became a laboratory job of analysis and investigation. A sample engine had been sent to us from France. Every piece of metal in this engine was examined by the chemists to determine its proper constituents, and from this original investigation new specifications were made for the steel producers. And the drawings of the engine were quite unsatisfactory from the point of view of American mechanics. They were found to be incorrect, and there were not enough of them. This deficiency required another study on the part of engineers, and a new set of drawings. All this fundamental work monopolized the time of a large force of draftsmen and engineers for several months, working under the direction of E. J. Hall and Frank M. Hawley. The engine could not be successfully built without this preliminary study—a part of manufacture of which the uninitiated have little knowledge.

The production of the Le Rhone engine might have been materially delayed by these difficulties, but for the organizing ability of the executives who handled the contract. While the metallurgists were specifying the steel of the engine parts and the engineers were drafting correct plans, the factory officials, with the assistance of the engine production division of the Air Service, were procuring machinery and tooling up the plant for the forthcoming effort. By the time this equipment was installed, the plans were ready, the steel mills were producing the proper qualities of metal, and all was ready for the effort. The Gnome-Le Rhone factories in France sent one of their best engineers, M. Georges Guillot, and he assisted in the work at the Union Switch & Signal Company. So rapidly was the whole development carried out that the first American Le

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Photo from Willys-Overland, Inc.

ASSEMBLING CURTISS "OX" ENGINES

Photo from Willys-Overland, Inc.

MACHINING SMALL PARTS FOR CURTISS "OX" ENGINES

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Photo from Air Service

INSTALLING HALL-SCOTT ENGINES IN STANDARD-J TRAINING PLANES

Photo from Air Service

MANUFACTURING PARTS FOR AIRPLANE ENGINES

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Rhones were delivered to the Government in May, 1918, considerably less than a year after the project had been assumed by the Union Switch & Signal Company, which had not received the plans of the engine until September, 1917. By the time the armistice was signed the company had delivered 1,057 Le Rhone engines. Subsequent contracts had increased the original order to 3,900 Le Rhones, all of which would have been delivered before the summer of 1919, had the coming of peace not terminated the manufacture. Although France is the home of the rotary aviation engine, M. Guillot certified to the Aircraft Board that these American Le Rhones were the best rotary engines ever built.

When it came to the selection of fixed cylinder engines for our advanced training program, all indications pointed to a single one, the Hispano-Suiza engine of 150 horsepower. This was a tried and true engine of the war, tested by a wealth of experience and found dependable. France had used it extensively in both training and combat planes. In 1916 it had been brought to the United States for production for the Allies, and when we entered the war the Wright-Martin Aircraft Corporation was producing Hispano-Suizas in small quantity. By the early summer of 1917, however, the motor had fallen behind in the development of combat engines, because of the increasing horsepowers demanded by the fighting aces on the front; but it was still a desirable training engine and could, if necessary, be used to a limited extent in planes at the front.

The plane adopted by the American aircraft authorities for this type of advanced training was known as the Curtiss "JN-4H." It was readily adapted to the use of the Hispano-Suiza 150-horsepower engine. Contracts for several thousand of these engines were placed with the Wright-Martin Aircraft Corporation, and up to the signing of the armistice 3,435 engines were delivered. Before we could start production of this engine, it was necessary for the Government to arrange with the Hispano-Suiza Company for the American rights to build it, this arrangement including the payment of royalties. Incidentally, it is interesting to note that royalty was the chief beneficiary

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of the royalties paid by the American Government, King Alfonso of Spain being the heaviest stockholder of the Hispano-Suiza Company.

Although our policy permitted us to produce a second training engine of the fixed-cylinder type, no engine other than the Hispano-Suiza was taken up by us. A number presented their claims for consideration, but they were one and all rejected. Among these were the Curtiss engines "OXX" and "V." A few of both of these had been used by the Navy, but neither one seemed to the Signal Corps to meet the requirements. The Sturtevant Company had developed a 135-horsepower engine and built a few; and Thomas Brothers, at Ithaca, New York, had taken the Sturtevant engine and modified it in a way which, they maintained, improved it, although the changes had not substantially increased the horsepower. This engine was rejected on the ground that it was too low in horsepower to endure as a useful machine through any considerable period of manufacture, and also because it was too heavy per horsepower to accomplish the best results.

To sum up, our training program was built around the above-named engines—the Curtiss "OX" and the Hall-Scott "A7A" for the elementary training machines; the Gnome and Le Rhone, for the rotary engine types of planes in the advanced training; and the Hispano-Suiza 150-horsepower, for the advanced training in fixed-cylinder-engine machines. Between September 1, 1917, and December 19, 1918, we sent to twenty-seven fields 13,250 cadets and 9,075 students for advanced training. They flew a total of 888,405 hours and suffered 304 fatalities, or an average of one fatality for every 2,922.38 flying hours. At one field the training fliers were in the air 19,484 hours before there was a single fatality; another field increased this record to 20,269 hours; and a third made the extraordinary record of one casualty in 30,982 flying hours. Although we do not possess the actual statistics, the best unofficial figures show that the British averaged one fatality to each 1,000 flying hours at their training camps, the French one to each 900 flying hours, and the Italian one to

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each 700 flying hours. These figures are significant, although varying conditions in the types of training programs may account to some extent for the wide differences in numbers of casualties at American as compared with Allied training camps.

But while we were producing engines for the training airplanes, both elementary and advanced, we were not staking our whole combat program on the Liberty engine alone, although we expected it to be our main reliance in our battle machines. Our organization, both at home and abroad, was on the alert continuously for other engines which might be produced in Europe or the United States and which would be so far in advance of anything in use by the air fighters in Europe in 1917 as to justify our production of them on a considerable scale.

One of these motors which seemed to promise great results for the future was the Rolls-Royce, which had even then, in 1917, taken its place at the head of the British airplane engines. Considerable difficulty was experienced in reaching a satisfactory arrangement with the Rolls-Royce Company. We expected to duplicate this engine at the plant of the Pierce-Arrow Motor Car Company, at Buffalo, New York, but the British concern objected to this arrangement on the ground that the Pierce-Arrow people were commercial competitors. It was several months before we could agree on a factory and arrive at a contract satisfactory to both sides. Meanwhile the Liberty engine had scored its great success, and the expected enormous production of Liberties tended to cool the enthusiasm of our aircraft authorities for the Rolls-Royce, as it was evident that the Liberty itself would be as serviceable and as advanced in type as the British product.

The Rolls-Royce Company wished to manufacture here its "190," an engine developing from 250 to 270 horsepower; and for this effort it was prepared to send to the United States at once a complete set of jigs, gauges, and all other necessary tooling of the Rolls-Royce plant. With this equipment ready at hand, the company expected to produce about 500 American-built Rolls-Royce engines before the 1st of July, 1918.

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But so rapidly was the evolution of aircraft engines going ahead that even during the time of these negotiations it became evident that something more than 250 horsepower would soon be needed in the fighting planes on the western front. We therefore abandoned the Rolls-Royce model 190 and started negotiations for the 270-horsepower engine, the latest and most powerful one produced by the Rolls-Royce Company. But for this engine the British concern could not furnish the tooling, which would have to be made new in this country, and this handicap would reduce the schedule of deliveries. As a result no American-built Rolls-Royce engine was ever made.

Another disappointing experience in attempting to produce a foreign-designed engine in this country was the project to bring the manufacture of Bugatti engines to the United States. When our European aircraft commission arrived in France, the first experimental Bugatti engine had just made its appearance. It was apparently a long step in advance of any other engine that had been produced. This French mechanism was a geared 16-cylinder engine. It weighed approximately 1,100 pounds and was expected to develop 510 horsepower. It seemed to be the motor to supplement our own Liberty engine construction. It was heavier than the Liberty, but it was also much more powerful. The first Bugatti engine built in France was purchased by the Bolling commission and hurried to the United States with the urgent recommendation that we put it into production immediately and push its manufacture as energetically as we were pushing that of the Liberty engine.

The Signal Corps acted immediately upon this advice and prepared to proceed with the Bugatti on a scale that promised to make its development as spectacular as that of the Liberty. The Dusenberg Motor Corporation, of Elizabeth, New Jersey, was even then tooling up for the production of Liberty engines. We took this concern from its Liberty work and directed it to assume leadership in the production of Bugattis. The Liberty engine construction had been centered in the Detroit district. We now prepared to establish a new aviation engine district in the East, associating in it such concerns as

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the Fiat plant at Schenectady, New York, the Herschell-Spillman Company of North Tonawanda, New York, and several others. For a time expectancy ran almost as high as enthusiasm for the Liberty engine. But the whole undertaking ended virtually in failure—another failure due to the tremendous difficulty of adapting foreign engineering plans to American factory production.

This was the story of it. In due time the sample Bugatti engine arrived, and with it were several French engineers and expert mechanics. But, once set up, the sample Bugatti engine would not function, nor was it in condition to run; for, as we discovered, during its test in France a soldier had been struck by its flying propeller, his body had been thrown twice to the roof of the testing shed, and the shocks had bent the engine's crank shaft. Then, too, we learned for the first time that the design and development of this engine had not been carried through to completion and that a great deal of work would be required before the device could be put into manufacture. The tests in France had disclosed the fact that so fundamental a feature as the oiling system needed complete readjustment; and this was only indicative of the amount of work yet to be done on the engineering side of the production. We did our best with this engine; but to redesign it and develop it so it could pass the severe fifty-hour test demanded by our Joint Army and Navy Technical Board was the work of months, and after that the tooling up of plants had to be accomplished. The American Bugatti was just getting into production when the armistice was signed, a total of only eleven engines having been delivered.

As we have seen, we were already building several hundred Hispano-Suiza 150-horsepower engines for our training planes. Soon after the arrival of our aircraft commission in France we were advised to go into the additional manufacture of the latest Hispano-Suiza geared engine of 220 horsepower. The Washington office at once arranged with the Wright-Martin Aircraft Corporation, which was building the smaller Hispano-Suizas, to undertake also the production of this newer model.

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The preparations for this manufacture had gone on in the Wright-Martin plant for a considerable period, when further advice from Europe informed us that the Hispano-Suiza 220 was not performing successfully on account of trouble with the gearing. This fact, of course, canceled the new contract with the Wright-Martin Corporation, the incident being another of those ups and downs with which the undertaking was replete.

Along in the summer of 1918 the Hispano-Suiza designers in Europe brought out a 300-horsepower engine. By this date the development of military flying had made it clear that engines of such great horsepower could be used advantageously on the smaller planes. But the engine plants of the Allied countries were already taxed to their capacities by their existing contracts, and the demands of these countries for high-powered engines could not be supplied unless we in America could increase our manufacturing facilities even further. In following out this ambition, we placed contracts for the production of 10,000 Hispano-Suiza 300-horsepower engines. Of these, 5,000 were to be built by the Wright-Martin Aircraft Corporation. To enable this company to fulfill the new contract, we leased to it the government-owned plant in Long Island City which had formerly been owned by the General Vehicle Company. The other 5,000 of these engines were to be built by the Pierce-Arrow Motor Car Company at Buffalo. We also contracted for the entire manufacturing facilities of the H. H. Franklin Company of Syracuse, New York, to aid both the Wright-Martin Corporation and the Pierce-Arrow Company in this contract. The first of these high-powered Hispano-Suiza engines were expected to be delivered in January, 1919. This project, of course, was interrupted by the armistice.

To summarize the complete engine program of the aviation development, the total of contracts for engines provided for the delivery of 100,993 engines, divided as follows:

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OX	9,450	Hispano-Suiza: 150 horse-power	4,000
A7A	2,250	Hispano-Suiza: 300 horse-power	10,000
Gnome	342	Bugatti	2,000
Le Rhone	3,900	Liberty-12	56,100
Lawrence	451	Liberty-8	8,000
Hispano-Suiza: 180 horse-power	4,500		

The delivery of aviation engines of all types to the United States Government—engines produced as part of our war program—was as follows, by months:

July, 1917	66	April, 1918	2,214
August, 1917	139	May, 1918	2,517
September, 1917	190	June, 1918	2,604
October, 1917	276	July, 1918	3,151
November, 1917	638	August, 1918	3,625
December, 1917	596	September, 1918	3,802
January, 1918	704	October, 1918	5,297
February, 1918	1,024		
March, 1918	1,666	Total	28,509

The production by types was as follows to November 29, 1918:

OX	8,458	Gnome	280
Hispano-Suiza	4,100	A7A	2,250
Le Rhone	1,298	Bugatti	11
Lawrence	451	Liberty	15,572

At the signing of the armistice the United States had produced about one-third of the engines projected in its complete aviation program.

Of the output of training engines to November 29, 1918, the various airplane plants took 9,069 for installation in planes, 325 (all these being Le Rhone rotaries) went to the American Expeditionary Forces in France, 515 (all Hispano-Suizas) were taken by the Navy, a single "A7A" model was sent to one of the Allied countries, and 6,376 engines were sent directly to the training fields. Of the combat engines pro-

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duced to November 29, 1918 (which classification includes all the Liberties, the two more powerful types of the Hispano-Suiza, and the Bugatti engine), 5,327 went to the various airplane plants for installation in planes, 5,030 were sent directly to the American Expeditionary Forces, 3,746 were turned over to the Navy, 1,090 went to the several Allied nations, and 941 were taken by the training fields.

The shipment of aviation engines to Europe, however, does not imply the immediate use of them by our airplane squadrons at the front. In this context, shipment to the American Expeditionary Forces means the shipment of engines from the American factories producing them. As a matter of fact, several months usually elapsed between the dispatch of an engine from an American shop and its actual arrival with the Air Service in France; and even then another month might be required to put the engine into actual service. Of the 5,000 and more aviation engines sent to France by the American engine producers, other than those installed in their planes, less than 3,000 are recorded in the annals of the American Expeditionary Forces as having been received up to the end of December, 1918, the missing 2,000 being in that period either somewhere in transit or in warehouses on the route to their destination.

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CHAPTER XX

AVIATION EQUIPMENT AND ARMAMENT

ON one of the early days of the World War a Russian aviator, aloft in one of the primitive airplanes of that time, was locating the positions of the enemy when he chanced upon a German birdman engaged in a similar mission. In that ancient period—for it seems ancient to us now, although less than seven years have elapsed—actual fighting in the air was unknown. The aviators had no equipment for battle; indeed, it was doubtful if it had occurred to either side to keep down the enemy's aircraft by the use of armed force borne upon wings. In the first months of aviation in the World War the fliers of both sides recognized a sort of *noblesse oblige* of the air, which, if it did not make for actual friendship or fraternizing between the rival air services, at least amounted to a respect for each other, often evidenced by an innocuous waving of hands as hostile flying machines passed. But now the wounds of war had begun to smart; and when the Russian saw the German flier going unhindered upon a work that might bring death to thousands of soldiers in the Czar's army, a sudden rage filled his heart, and he determined to bring down his adversary, even at the cost of his own life. Maneuvering his craft, presently he was flying directly beneath the German, in the same direction and but a short distance below his enemy's plane. Then, with a pull on his control lever, the Russian shot his machine sharply upward, hoping to upset the German and to escape himself. The machines collided, and both crashed to the ground. This was probably the first aërial combat of the war.

It seems strange to us to-day to reflect that the highly complicated and standardized art of fighting with airplanes was

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developed entirely during the World War and, indeed, was started only after the war had been in progress for several months. Yet so it was. At the beginning of the war there was no such thing as armament in aircraft, either of the offensive or the defensive sort. It is true that a small amount of experimentation in this direction had occurred prior to the war and also in the early months of fighting, but it was not until the summer of 1915 that air fighting, as it is so well known to the entire world to-day, was begun.

In this country we had successfully fired a machine gun from an airplane in 1912; and at the beginning of the war the French had a few heavy airplanes equipped to carry machine guns. Yet in August, 1915, Major Eric T. Bradley, of the United States Air Service, then a flight sublieutenant in the Royal Flying Corps, frequently flew over the lines hunting for Germans; and his offensive armament consisted of a Lee-Enfield rifle or, sometimes, a 12-gauge double-barreled shotgun. The aviators in those pioneer days usually carried automatic pistols, but the danger to the other side from such weapons was slight, owing to the great difficulty of hitting an object moving as swiftly as an airplane travels. The earlier planes also packed a supply of trench grenades for dropping upon bodies of troops. Another pioneer offensive weapon for the airplane was the steel dart, which was dropped in quantities upon the enemy's trenches. Great numbers of these darts were manufactured in the United States for the Allies, but the weapon proved to be so ineffective that it had but a brief existence.

It is said that, before the pilots carried any weapons at all, the first war aviators used to shoot at each other with Very pistols, which projected Roman-candle balls. The start of air fighting may be said to have come when the Lewis machine guns were brought out for use in the trenches. Presently these ground guns were taken into the planes and fired from the observers' shoulders. Then for the first time war flying began to be made a hazardous occupation by the enemy's attentions. It was soon discovered that the machine gun was the most

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effective weapon of all for use on an airplane, because only with rapid firers could one hope successfully to hunt such swiftly moving prey as airplanes. It had become patent to the strategists that it was of supreme importance to keep the enemy's aircraft on the ground. Hence invention began adapting the machine gun to airplane use. The swiftest planes of all were those of the single-seater pursuit type. It was obviously impossible for the lone pilot of one of these to drop his controls and fire a machine gun from his shoulder. This necessitated a fixed gun that could be operated while the pilot maintained complete control of his machine, and this necessity was the mother of the invention known as the synchronizing gear.

This ingenious contrivance, however, did not come at once. Most of the war planes were of the tractor type; that is, they were built with the engine and propeller in front. This arrangement made them, for maneuvering and defensive tactics, superior to planes of the pusher type, with their propellers at the rear. The first fixed machine gun was carried on the upper plane of a biplane, so as to shoot over the arc described by the propeller. With the gun thus fixed parallel to the line of flight, the pilot needed only to point the airplane itself directly at the target to have the gun trained on its objective. But such an arrangement proved to be unsatisfactory. A single belt or magazine of cartridges could, indeed, be fired from the gun, but there was no more firing on that trip, because the pilot could not reach up to the upper plane to reload the weapon.

Presently, then, the fixed gun was brought down into the fuselage and made to fire through the whirling propeller. At first the aviators took their chances of hitting the propeller blades; and sometimes the blades were armored at the point of fire, by being sheathed in steel of a shape calculated to cause the bullets to glance off. This system was not satisfactory. Then, since a single bullet striking an unprotected propeller blade would often shatter it to fragments, attempts were made to wrap the butts of the blades in linen fabric to prevent this splintering; and this protection actually allowed several shots to pierce the propeller without breaking it. This was the state

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of affairs on both sides early in 1915. The French Nieuports had their fixed guns literally shooting through the propellers, the bullets perforating the blades if they did not wreck them. As late as February, 1917, Major Bradley, who was by that time a flight commander in the British service, worked a Lewis gun over the Bulgarian lines with the plane propellers protected only by cloth wrappings.

All this makeshift operation of fixed machine guns was changed by the invention of the synchronizing device. This was an appliance for so controlling the fire of the fixed gun that the bullets miss the blades of the flying propeller and pass on in the infinitesimal spaces of time during which the line of fire ahead of the gun is clear of obstruction. The term "synchronizing" is not accurate, for it implies that the gun fires after each passage of a propeller blade across the trajectory. That is not the fact. The propeller revolves much more rapidly than the gun fires. The device is also called an "interrupter"—another inexact term, for the fire of the gun is not interrupted, but only caused at the proper moments. Technicians prefer the name "gun control" for this mechanism.

Who first invented the synchronizer is a matter of dispute, but all observers agree that the Germans, in the Fokker monoplanes of 1915, were the first to use it extensively. Not until some time after this did the Allies generally install similar devices. Some have attributed the original invention to the famous French flier, Roland Garros.

Two types of synchronizers were developed, one known as the hydraulic type and the other as the mechanical. In the operation they are somewhat similar. In each there is a cam mounted on the engine shaft so that the revolutions of the shaft actuate a plunger. The plunger passes on the impulses to the rest of the mechanism. In the mechanical control the impulse is carried through a series of rods to the gun, causing the latter to fire at the proper moments. In the hydraulic control the impulse is transmitted through oil held at a pressure in a system of copper tubes. The hydraulic synchronizer is known as the Constantinisco control, commonly called the "C. C.,"

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after the military fashion of using initials. This was the device copied for American planes in the war.

In April, 1917, we knew practically nothing about the use or manufacture of aircraft guns. We had used airplanes at the Mexican border, but not one of them carried a machine gun. The Lewis gun, which is a flexible type of aircraft weapon mounted on a universal pivot and fired by the observer in a two-place plane, was being manufactured by the Savage Arms Corporation for the British Government; but we had never made a gun of the fixed type in this country, nor did we know anything about the construction or manufacture of synchronizers.

One special requirement of the aircraft machine gun is that it must be reliable in the extreme. It is bad enough to have a gun jam on the ground, but in the air it may be fatal, for little can be done there to repair the weapon. A jam leaves the gunner at the mercy of his adversary. In the production of aircraft armament there must not only be special care in the manufacture of the guns, but the ammunition, too, must be as perfect as human accuracy can make it. The cartridges must be either hand picked and specially selected from the run of service ammunition, or else manufactured slowly and expressly for the purpose, with minute gauging from start to finish of the process.

Another requirement for the aircraft gun is that it must function perfectly in any position. On the ground a machine gun is fired essentially in an horizontal position, but the airman dives and leaps in his maneuvering and must be able to shoot at any instant.

Aircraft guns are subject to extreme variations of temperature; and they must be certain to function perfectly in the zero cold of the high altitudes, regardless of the contraction of their metal parts.

Moreover, such guns must be able to fire at a much greater rate than those of the ground service. Five hundred shots a minute is regarded as sufficient for a ground gun, but aircraft guns have been brought up to a rate of fire as high as 950

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to 1,000 shots. The Browning aircraft gun, never used by us, but in process of development when the armistice was signed, had been speeded up to 1,300 shots a minute, with all shots synchronized to miss the blades of the propeller. There is no such thing as too high a rate of fire in the air. Suppose an airplane were flying past a long, stationary target, such as a billboard, at the relatively slow speed of 100 miles an hour. Assume on this plane a flexible machine gun aimed at the billboard at right angles to the line of flight. If this is a fast machine gun, it may shoot 880 times a minute, at which rate the shots will come so fast that the explosions will merge into a continuous roar. Yet the bullets fired at such a rate from a machine moving at even such low speed will be spaced out along the billboard at intervals of ten feet. But most of the fighting planes traveled much faster than 100 miles an hour; and it was entirely possible for two antagonists in the air to aim at each other with complete accuracy and yet pass unscathed through the lines of fire. The faster the aircraft gun fired, the better the chances of bringing down the enemy plane.

The Lewis gun, invented by Colonel Lewis, of the United States Army, was the weapon most generally used by the Allies as the flexible gun for their airplanes. It was operated on a universal mount which permitted it to be pointed in any direction. The Lewis aircraft gun was the ground gun modified, principally, by stripping it of the cooling radiator and by adding to it a gas check to reduce the recoil. The Lewis was fed by a drum magazine, a more desirable feed for flexible guns than any belt system. (The German flexible gun, the Parabellum, had the unsatisfactory belt feed.)

The only successful weapon of the fixed type developed in the war before we became a belligerent was the Vickers. We were manufacturing Vickers guns in the United States prior to April, 1917; but when the Signal Corps faced the machine gun problem, in September, 1917, it found that the infantry branches of the Army had contracted for the entire Vickers production in this country. Accordingly, the equipment division of the Signal Corps, in the face of marked opposition, took

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up the development of the Marlin gun as an aircraft gun of the fixed type. This gun proved to be extraordinarily successful and was regarded by our flying service and by the aviators of the Allies as being the equal of the Vickers. When there came the need of tank guns, in June, 1918, the Aircraft Board, which had succeeded the Signal Corps as the director of aërial activities, was able to supply the tanks with 7,220 Marlin machine guns within two weeks—an additional justification of the Signal Corps' pioneer enthusiasm for the Marlin.

The first order for Marlin guns was placed on September 25, 1917, and over 37,500 of them had been produced before December, 1918. The Marlin-Rockwell factory began producing 2,000 guns a month in January, 1918, and increased this number rapidly until as many as 7,000 guns were built in one month. The Marlin gun shot at the rate of 600 to 650 a minute and was fed by a belt of the disintegrating metal-link type.

Of Lewis guns, which we adopted as our flexible weapon, more than 35,000 were delivered to the Air Service up to December, 1918. In February, 1918, the Savage Arms Corporation built 1,500 of them, increasing their monthly deliveries until, in October, 1918, they turned out 5,448. The Lewis gun which the British had been using carried forty-seven cartridges in its magazine. A notable accomplishment in the manufacture of Lewis guns for our use was the increase of the magazine capacity to ninety-seven cartridges.

In each of our De Haviland–4 planes we installed two Marlin fixed guns, each firing at the rate of 650 shots a minute; and we equipped the weapons with Constantinisco controls, to give the plane a maximum fire of 1,300 shots a minute through the blades of a propeller whirling at rates as high as 1,600 revolutions a minute. Four fixed guns have also been successfully fitted to one plane and timed so that none of the bullets strike the propeller blades.

At the time the armistice was signed, the rate of production of special aircraft ammunition—a classification including tracer bullets, incendiary bullets, and armor-piercing bullets—

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exceeded 10,000,000 rounds a month. The original estimate of the quantity of ammunition our flying service should have was later greatly increased because the squadrons at the front began installing as many as four guns on a single observation plane. Although different aviators had their own notions about the loading of ammunition belts, certain sequences in the use of the three types of special ammunition were usually observed. First, usually, came the tracer cartridge, which assisted the gunner in directing his aim; then two or three armor-piercing cartridges, relied upon to injure the hostile engine or tap the gasoline tank; and finally one or two incendiary cartridges to ignite the enemy's gasoline as it escaped, sending him down in flames. Such a sequence would be repeated throughout the ammunition belt or magazine container.

The belts for the fixed guns carried a maximum of 500 rounds of cartridges. The belt which we furnished to our fliers at the front was made of small metallic links fastened together by the cartridges. As the gun was fired and the cartridges were ejected, the links fell apart and cleared the machine through special chutes. The total production of such belting in this country amounted to 59,044,755 links. Although the links were extremely simple in design, the great accuracy required in their finish made production of them a difficult manufacturing undertaking. The production and inspection of each link involved over thirty-six separate operations. It actually cost more to inspect belt links than to manufacture them.

We produced 12,621 British unit sights for airplane guns and sent 1,550 of them overseas. We also bought an adequate number of small electric heaters to keep the gun oil from congealing in the cold of high altitudes.

A novel undertaking for our photographic manufacturers was the production of the so-called gun cameras which are used to train airplane gunners in accuracy of fire. Target practice with a machine gun in an airplane is dangerous to the innocent bystander; and it was found to be impracticable, moreover, to tow suitable targets for actual machine gun fire.

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Therefore, early in the war, the air services of the Allies adopted the practice of substituting cameras for the machine guns on the practice planes. One of these gun cameras, invented by Thornton Pickard, of Altrincham, England, imitated in design a Marlin aircraft machine gun; and in order to make a picture with it, the gunner must go through the same movements that he would employ in firing a Marlin gun. If the gun were pointed directly on the target, the target would appear squarely in the center of the picture taken; and this showed the gunner's accuracy as well as if he had fired cartridges from the actual weapon.

These gun cameras were of two sorts. One type took a single picture each time the trigger was pulled. The other took a number of pictures automatically, at a speed approximately that of the firing of a machine gun. This latter type was much the same as a moving-picture camera, the resulting film being a string of silhouettes of the target, each exposure showing whether the aim of the gunner was exact at the instant the picture was taken.

In September, 1917, the Eastman Kodak Company began the development of a camera gun of the "burst" or automatic moving-picture type. After our authorities had seen the model, the Navy ordered a number of them, and the Air Service placed increasing orders for these instruments until 1,057 had been produced and delivered to the Government by November, 1918. This camera was not used in the fixed airplane guns, but was designed to train the operators of the flexible Lewis gun. The camera exactly replaced the ammunition magazine on a Lewis gun. Of the single-shot gun cameras, 150 were delivered during the hostilities. This design was obtained from Canada and duplicated here.

The use of the so-called Bromotype paper in gun cameras was one of the interesting phases of this development. As everyone acquainted with photography knows, a picture is ordinarily made by exposing a sensitized plate or film, developing it to make a negative, and then exposing sensitive print paper to the light that comes through the negative,

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thus reversing the lights and shadows and creating a positive in the exact semblance of the subject photographed. A concern in Cleveland, Ohio, the Positype Company, produced Bromotype paper which could be exposed directly in the camera, coming out of the developing process as a positive without the intervention of a film or plate negative. Bromotype paper is much more highly sensitized than ordinary print paper, so that it may be adequately exposed in an instantaneous, high-speed snapshot. The exposure is then developed in the ordinary way in the dark room, the familiar negative image appearing on the surface in the ruby light of the lantern. At this point the special developing process enters. The paper negative, without being fixed, is immersed in a bath of chemicals that dissolves away the sensitized surface which has been oxidized by the light from the camera lens,—that is, the image,—leaving on the paper only the unoxidized, or unexposed, parts of the sensitization. The paper now presents an unbroken, white surface. It is then redeveloped by a special solution, and the picture in its true values of light and shade comes into existence. The entire development and finishing of this paper takes only two and one-half to three minutes. Under this system, of course, only one finished print of each exposure can be made; but the airplane gunners needed only one print to show their aim. Positype paper was admirably adapted for use in the airplane gun cameras; and because of its cheapness and the simplicity and rapidity of its use, it was rapidly supplanting film at the training camps in this country when the armistice was signed.

AIRPLANE BOMBS

The American production of bombs to be dropped from airplanes was not started so soon as production in some of the other branches of ordnance development, because of numerous difficulties encountered in working up the designs of this new *matériel.* Although aërial bombing was steadily increasing in effectiveness and magnitude when hostilities ended, this kind of fighting was a development that came relatively late in the

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war; and the lack of perfected standards at the time this country became a belligerent helped to impede our program. Some of the bombs first designed and put into production were later rejected by our forces in France; they had become obsolete before being shipped overseas. We managed to manufacture a great quantity of unloaded bombs by the time the armistice was signed; enough, in fact, to provide for the Army's needs during another year of warfare. These had still to be loaded with explosives before they were ready for use. We lacked adequate facilities for loading bombs with explosives, although these facilities were being provided rapidly when the war ended. The thousands of completed American bombs remained unloaded, and practically all the bombs used by our fliers in France were of foreign manufacture.

Military science had had some small experience with aërial bombing before the World War. Italian aviators had dropped bombs of an ineffective sort during Italy's war in Africa. When Mexico was having a civil war in 1914, American air-sailors of fortune on one side or the other dropped bombs on troops from their planes. In the World War the first nation to attempt bombing on any systematic scale was Germany, who sent her Zeppelins over London and Paris early in the conflict and released bombs upon the heads of the helpless civilians. This early effort, impressive as it was, entailed difficulties out of all proportion to the actual damage done to the city of London, for instance, primarily because Germany had not yet produced effective aërial bombs. The frightful scenes and noises of a bombing raid probably did more to reduce morale in those early days than the destruction caused by the exploding missiles.

It is an exceedingly difficult trick to drop a bomb from any considerable altitude and hit what you are aiming at. The speed of the airplane, its height above the ground, the shape of the bomb, and the currents of air acting on the falling missile influence its line of flight. The aviator approaching an enemy target drops the bomb long before his airplane is directly above the object aimed at. The line of the bomb's flight is a parabolic curve. The speed at which the airplane

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travels at first propels the bomb forward, almost as if it had been shot from a stationary gun. The downward velocity of the bomb increases rapidly and soon becomes so great in proportion to its velocity forward that the course of the missile bends sharply downward until, as it nears the ground, it is falling in a nearly vertical line. It is evident that accurate bomb dropping is an art attained only by much practice on the part of the aviator.

The latest bombing machines were equipped with sights which enabled the birdman to drop these deadly objects with greater accuracy than had been possible earlier in the war. Some of the expert European bombers scorned the new inventions, and preferred to continue the use of makeshift sights which they themselves had invented and installed on their planes; but the average accuracy of bomb dropping was considerably greater after bomb sights came into general use. These sights were adjusted to height, air speed, and velocity of wind. When these adjustments had been made, the two sighting points were in such position that, if the bomb were dropped when the target was in line with them, an accurate hit would be registered.

We adopted a British sight, tested and found satisfactory by the Royal Flying Corps, and known as the High Altitude Wimperis, and in the United States as the Bomb Sight Mark I–A. On November 11, 1918, American factories, working on contracts placed by the Ordnance Department, had produced 8,500 of these. The job of turning out this intricate mechanism was handed over to Frederick Pearce & Company, of New York City, in January, 1918. Later in the year, additional contracts were given to the Edison Phonograph Works and to the Gorham Manufacturing Company. These contracts called for 15,000 sights. By December 12, 1918, these concerns had completed a total of 12,700.

Airplane bombs are shaped so as to offer the least possible resistance to the air. They have fins on their tails to steady them lest they tumble over and over. On the smaller types of bombing planes, such as the De Haviland–4, the bombs were

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Photo from McCord & Company

FOUNDRY IN AËRIAL BOMB PLANT

Photo from McCord & Company

PRESSES USED IN MAKING DROP BOMBS

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Photo from Parrish & Bingham Company

MAKING INCENDIARY BOMBS

Photo from McCord & Company

MACHINING AIRPLANE BOMBS

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usually carried underneath the lower wings or under the fuselage, hanging horizontally by hooks or fastened by bands around the bodies of the bombs, according to their type. The bombs were dropped by a quick-release mechanism operated by a small lever within the fuselage. The production of these release mechanisms, of which several types were made, was one of the troublesome jobs in connection with the airplane bombing.

All bombs carried on the planes were either suspended under the wings or fuselage of the plane or contained in a compartment in the fuselage. The manner of carrying and the design of the release mechanism were determined by the type of plane used. Since the weight-carrying capacity of the planes was limited, release mechanisms had to be designed with a view to lightness as well as safety. These mechanisms were so designed that the observer could release any desired number of bombs, either as a salvo or in a "trail fire," and the order of releasing had to be so arranged that the balance of the plane would be disturbed as little as possible; that is, if bombs were carried under the wings, they had to be released alternately from each wing. All bombs were fitted with a safety mechanism which enabled the observer to drop them either "armed" or "safe"—*i.e.*, so that they would explode or not, as desired. An occasion might occur to compel the aviator to get rid of his bombs over his own lines. These points were all taken care of in the design of the release mechanism, and absolute control was maintained by the observer through an operating-control handle placed in the observer's cockpit.

The bombs used by our fliers and by the fliers of the other nations at war were of three distinctive types—demolition bombs, fragmentation bombs, and incendiary bombs.

Our Ordnance Department built demolition bombs in five different weights: 50 pounds, 100 pounds, 250 pounds, 500 pounds, and, finally, the enormous bomb weighing 1,000 pounds—half a ton. The most frequently used demolition bombs, however, were those of the 100-pound and 250-pound sizes. The demolition bombs were for use against ammunition

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dumps, railways, roads, buildings, and all sorts of heavy structures where a high-explosive charge was desired. These bombs had a shell of light steel which was filled with trinitrotoluol—T. N. T.—or some other explosive of great destructive power. The charge was set off by a detonator held apart from the dangerous contents of the bomb by a pin. As the bomb was released by the mechanism, the pin was automatically drawn out, and the detonator slid down into position ready to explode the bomb.

Our first contract let for drop bombs of any type was given to the Marlin-Rockwell Corporation in June, 1917. This contract was for the construction of 5,000 heavy drop bombs of the design known as the Barlow, and also for 250 sets of release mechanisms for this bomb. We were able to go ahead with the production of this bomb at this early date because it was the only one of which we had completed designs and working drawings when we entered the war. In November, 1917, this order was increased to 13,000, and in April, 1918, to 28,000. The Barlow bomb, however, was destined never to cut any figure in our fighting in France. The production was slow, because of the necessity of constant experimentation to simplify a firing mechanism which was regarded as too complicated by the experts of the War Department. Finally, in June, 1918, when 9,000 of these bombs and 250 sets of release mechanisms had been produced, a cablegram came from the American Expeditionary Forces canceling the entire contract.

Meanwhile, the final type of demolition bomb, known variously as the Mark I, II, III, IV, V, or VI, depending upon its size, had been developed here. In December, 1917, a contract for 70,000 of the size known as Mark II, weighing twenty-five pounds, was given to the Marlin-Rockwell Corporation. But in June the American Expeditionary Forces informed us that this bomb, because of its small explosive charge, would not be of value to the Air Service abroad; and the contract was cut down to 40,000 bombs, which number the Army could use in training its aviators. By the end of November, 1918,

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bomb bodies of the Mark II size had been completed to the number of 36,840.

By the end of March, 1918, we had developed here a series of demolition bombs that promised to meet every need of our Air Service abroad for projectiles of their class. We let contracts for the manufacture of 300,000 of the 50-pound (Mark III) size, these contracts being reduced later to a total of 220,000. The manufacturers were the A. O. Smith Corporation, an automobile parts concern of Milwaukee, Wisconsin; the Edward G. Budd Manufacturing Company of Philadelphia; and Hale & Kilburn of Philadelphia. Six months later the A. O. Smith Corporation had reached a production of 1,200 of these bombs a day, and they completed their contract in October. Both the other concerns also completed their contracts in the autumn of 1918.

The A. O. Smith Corporation had tooled up their factory so as to become one of our largest producers of airplane bombs. In addition to the contract already mentioned, during 1918 this concern received orders for approximately 300,000 demolition bombs of the 100-pound (Mark I) size. By November 11, 1918, they had turned out 153,000 of these and had developed a capacity for building 7,000 drop bombs daily. Another large manufacturer of drop bombs was McCord & Company, of Chicago, a concern which in 1918 received orders for nearly 100,000 bombs of the 250-pound, 550-pound, and 1,000-pound sizes. By the day the armistice was signed this concern had produced 39,400 completed bombs. These bombs were the heaviest and largest ones intended for use by our service abroad.

The fragmentation bombs differed from the demolition bombs in that they had thick metal walls and, consequently, smaller charges of explosive. They threw showers of fragments like those of high-explosive artillery shell. The demolition bombs contained the maximum possible amount of explosive and produced destruction by the force of explosion. Fragmentation bombs always had instantaneous firing mechanisms, whereas demolition bombs were usually provided with de-

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layed fuses, allowing them to penetrate the target before explosion. The fragmentation bombs produced by the Ordnance Bureau were smaller than the demolition type, the size most commonly used weighing twenty-four pounds. These bombs had thick cases and were constructed so that they would explode a few inches above the ground. As the bombs reached a velocity downward of over 500 feet a second, the mechanism had to operate to an accuracy of less than one-thousandth of a second. They were designed for use against bodies of troops.

The fragmentation bombs were a late development in this class of work. The timing device to explode the bomb at the proper distance from the ground was undertaken by three concerns. Contracts for approximately 600,000 of these devices were let in July, 1918. The John Thomson Press Company of New York City completed its contract for 100,000 mechanisms by the end of October, 1918. The National Tool & Manufacturing Company of St. Louis completed its contract for 100,000 shortly after the armistice was signed. The Yale & Towne Manufacturing Company, Stamford, Connecticut, which had contracted to build approximately 400,000 of these devices, had turned out 150,000 by the end of November, 1918. Other concerns which manufactured various parts for the fragmentation bombs were the American Seating Company of Grand Rapids, Michigan, makers of school desks and seats, and the Dail Steel Products Company of Lansing, Michigan.

Some idea of the quantity of fragmentation bombs in our program can be gained from the fact that the contract for the Cordeau-Bickford fuse used in the fragmentation bomb, let to the Ensign-Bickford Company of Simsbury, Connecticut, called for the manufacture of 550,000 linear feet of fuse, or more than 100 miles of it. The contracts for fuse were placed in August and September, 1918, and the Ensign-Bickford Company finished the job on November 7, four days before the armistice was signed.

The Government discovered that 3-inch shell which had been rejected for various reasons could be remachined and used to make these airplane fragmentation bombs. The various

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arsenals had a large supply of such shell in storage. In August and September, 1918, contracts were let to large numbers of concerns to convert over 500,000 of these shell into fragmentation bombs, and by November 30 nearly 21,000 of the new bombs had been delivered. The bombs made from 3-inch shell, so far as the machining of the bodies was concerned, were turned out in various quantities by the following firms:

Vermont Farm Machinery Company, Bellows Falls, Vermont.
Richmond Forgings Corporation, Richmond, Virginia.
Bethlehem Steel Company, Bethlehem, Pennsylvania.
Consolidated Car Heating Company, Albany, New York.
S. A. Woods Machine Company, South Boston, Massachusetts.
Westfield Manufacturing Company, Westfield, Massachusetts.
Wheeling Mold & Foundry Company, Wheeling, West Virginia.
A. P. Smith Manufacturing Company, East Orange, New Jersey.
Watervliet Arsenal, Watervliet, New York.
Keystone Machine Company, York, Pennsylvania.
McKiernan-Terry Drill Company, Dover, New Jersey.

The nose-firing mechanism for these bombs was produced by the Yale & Towne Manufacturing Company, Stamford, Connecticut; the National Tool & Manufacturing Company, St. Louis, Missouri; and the John Thomson Press Company, New York City. The rear cap stabilizer assemblies were produced by the Dail Steel Products Company, Lansing, Michigan, and the American Seating Company, Grand Rapids, Michigan.

The last item on the bomb program to come into production was the fragmentation bomb Mark II–B, which was an exact copy of the British Cooper bomb, the most effective bomb of this type in use by the Allied nations. Contracts for this bomb were let August 17, 1918, to the Lycoming Foundry & Machine Company, of Williamsport, Pennsylvania, and the Paige-Detroit Motor Car Company, of Detroit, Michigan. The former company, by December 1, was producing these bombs at the rate of 500 a day, and the latter was just coming into quantity production the first week in December.

When the United States entered the war no satisfactory incendiary bombs had yet been produced by any country, and

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a long period had to be given over to experimentation before quantity production could be attained. We produced two types of incendiary bombs, the first being of the scatter type, designed for use against light structures, grain fields, and the like, and the second of the intensive type, for use against large structures. Later on in our program we abandoned the manufacture of the scatter-type incendiary bombs, on cable instructions from abroad, as it was found that the wet climate made a bomb of this type of little value. The American intensive bomb, though it had not yet come up to our ideal and was in process of evolution during its manufacture, was regarded by our officers as more effective than any other bomb of its type in existence, since it produced a larger and hotter flame. Our intensive incendiary bombs weighed about forty pounds each and contained charges of oil emulsion, thermit, and metallic sodium, a combination of chemicals that burns with intense heat. These bombs were used against ammunition depots and any structures of an inflammable construction. The sodium in the charge was designed to have a discouraging effect upon anyone who attempted to put out the fire of the burning charge, for metallic sodium explodes with great violence if water is poured upon it.

Of the scatter bombs we built 45,000 before abandoning the manufacture, as we did in September, 1918. When hostilities ceased we had out contracts for 122,886 of the intensive bombs, and about 86,000 had been delivered ready for loading.

One of the large manufacturers of incendiary bombs was the Conron-McNeal Company, of Kokomo, Indiana, manufacturers of skates. The company had to equip its plant with new machinery especially for handling this novel manufacturing enterprise. In all, they produced 50,000 bombs and were turning them out at the rate of 400 a day when the armistice was signed. This concern was the pioneer in the manufacture, the subsequent contractors profiting by the experience of the Conron-McNeal Company, and consequently being able to obtain quantity production more quickly than the Kokomo plant had done. The Globe Machine & Stamping Company, of Cleve-

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land, Ohio, built 30,000 bombs and 36,400 firing mechanisms before hostilities closed, and eventually reached a production rate of 500 bombs and 1,000 firing mechanisms a day. Parrish & Bingham, also of Cleveland, produced 13,000, and were turning them out at the rate of 400 daily when the production was stopped. The C. R. Wilson Body Company, of Detroit, built 42,562 of the intensive bombs and reached a daily production of 500. The New Home Sewing Machine Company, of Orange, Massachusetts, manufactured 20,000 firing mechanisms for the scatter-type bombs.

One of the interesting phases of the bomb manufacturing program grew out of the necessity for target practice for our aviators. For this work we built dummy bombs of terra cotta, which cost about a dollar apiece. Instead of loading these bombs with explosive, we placed in each a small charge of phosphorus and a loaded paper shotgun shell, so that the bomb would eject a puff of smoke when it hit its object. The aviators could see the smoke puffs and thereby determine the accuracy of their aim. The Gathmann Ammunition Company of Texas, Maryland, was the first contractor for dummy bombs, building 10,000, which were delivered in the spring of 1918. In the spring and summer of 1918, the Atlantic Terra Cotta Company, the New Jersey Terra Cotta Company, both of Perth Amboy, New Jersey, and the Federal Terra Cotta Company of Woodbridge, New Jersey, each built 25,000 of these bombs. In September additional contracts for 50,000 dummy bombs were given to each of these three concerns, and another contract for 25,000 went to the Northwestern Terra Cotta Company of Chicago. By the end of November these concerns had delivered nearly 34,000 of the 175,000 bombs contracted for, and were turning them out at the rate of 1,300 a day. The Essex Specialty Company manufactured 10,000 phosphorus rolls for dummy bombs, and the Remington Arms-Union Metallic Cartridge Company supplied 10,000 shotgun shells for the first bombs produced. Later the Remington Arms Company produced 100,000 shotgun shells for dummy bombs.

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AIRPLANE PHOTOGRAPHIC SUPPLIES

In four days of the final drive of the Yankee troops in the Argonne district, the American photographic sections of the Air Service made and delivered 100,000 prints from negatives freshly taken from the air above the battle lines. This record is indicative of the progress made by military intelligence from the days when a commander secured information of the enemy's positions only by sending out patrols or from spies. The coming of the airplane destroyed practically all possibility for the concealment by day of moving bodies of men or of military works. Mere observation by the unaided eye of the airmen, however, soon proved incapable of properly utilizing the vantage point of the plane. The insufficient and often crude and inaccurate drawings brought in by the airplane observer were early succeeded by the almost daily photographing of the entire enemy terrain by cameras, which recorded each minute feature far more accurately than the human eye could possibly do. The airplane, to quote the common saying, had become the eye of the Army; but the camera was the eye of the airplane.

This entire development in military information-getting, from start to finish, was an evolutionary product of the World War. When the war broke out in 1914 there were no precedents for the military photographer to go by, nor had any specialized apparatus ever been designed by either side for his use. The first crude makeshifts were rapidly succeeded by more and more highly developed equipment. At the outset of the war, before anti-aircraft guns were brought to efficiency, it was possible for observation planes to fly at low altitudes and take satisfactory pictures with such photographic appliances as were then in common use. But as the "Archies" forced the planes to go higher in the air, special equipment had to be designed for longer distance work under such adverse conditions of vibration and speed as exist on airplanes. It is a tribute to the photographic technicians of the world that they were at all times able to produce equipment to meet these increasing demands. As the airplanes moved into higher altitudes, longer-

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focus lenses had to be employed, special dry plates developed, and special color filters provided to overcome the haze created by humidity in the long spaces between the cameras and the ground. When the war ended, cameras in common use were taking photographs at an altitude of four miles with such microscopic fidelity as to show even where a single soldier had recently walked across a field.

The American Army came into the war almost innocent of any information at all on the subject of war photography. Such technical information as the Allied nations had developed during the war had been most carefully guarded from us and from all other neutral countries, and what information we had was of a meager and conflicting sort. Although, in the early months of our participation, the Signal Corps, which then had charge of all phases of aërial warfare, made large purchases of motion-picture cameras, hand cameras, and view cameras, it was not until the end of 1917 that our officers were able to begin their real development of aërial photography. By this time we had received much valuable information from the foreign high commissions and samples of their earlier apparatus. Aërial photography had become one of the leading activities of the Air Service. In April, 1917, the British service had made 280,000 pictures at the front, and a great part of all flying was done to secure photographs. Moreover, the art was advancing at such a pace that methods and equipment in approved use at the front one week appeared likely to become obsolete the next.

For years America had been second to no country in photography, and it was to be expected that we should make notable contributions to the new science. It may indeed be asked why, with the experimental laboratories and the skilled technicians at our command, we did not start at once to develop our own aërial designs and equipment. Our officers, however, felt that such a course would be likely to duplicate much of the work already done by the Allied countries, who then stood ready to contribute the results of their experiences. Original research work here might, to be sure, result in the invention of equip-

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ment of superlative merit; but we would be sure, in the course of such an undertaking, to adopt methods which had been tried and discarded by the Allies, and which we ourselves should have to discard when experience had proved them to be without value.

The information in our hands in December, 1917, showed that the British system of air photography differed radically from the French. The French cameras made a relatively large negative, 18 by 24 centimeters in dimension, on a glass plate. The magazines of the French cameras held twelve plates, and extra magazines were carried in the plane. These cameras were fitted with lenses of relatively long focus—twenty inches. Three operations were necessary to make an exposure. The photographer must change the plate, set the focal-plane shutter, and press the release. When the negatives were developed, fixed, washed, and dried, prints were made by contact.

The British used a smaller-sized plate, 4 by 5 inches. Their cameras were equipped with the only lenses available in England in the early part of the war—lenses of relatively short focus, ranging from eight to twelve inches. Instead of making contact prints from these plates, the British made enlargements, 6½ by 8½ inches. In the earlier period of our development of aërial photographic apparatus, we were in the same position as the British in that we had no adequate supply of long-focus lenses. Therefore we followed the British designs of cameras and almost explicitly adopted the British system in the training of aërial photographers.

It had been our first thought to use films to a great extent on the front, for America was the country which had perfected the photographic film, and was therefore, presumably, best equipped in skill to adapt it to war uses. But plates had been used almost exclusively by the British, the French, and the Italians; and it appeared wisest to follow their experience at first, though all agreed that film, with its small bulk and weight, would be greatly superior for airplane use.

The Photographic Experimental Department of the Air

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Service, organized in January, 1918, faced as its major problem the design and test of aërial cameras and all their parts and accessories. Equally important were the problems of sensitive plates, papers, color filters, and photographic chemicals. The corps of photographic and optical experts in whose hands these matters were placed early secured the active coöperation of the chief manufacturers of photographic apparatus and materials in this country. In the laboratories in Washington, D. C., Langley Field, Virginia, and Rochester, New York, comprehensive development work was inaugurated, which led ultimately to the perfection of new designs of cameras and the development of plates and other photographic materials equal or superior to any available abroad.

The first airplane camera which it was decided to put into production in America was a close copy of the British Type "L," which use had proved to be one of the best mechanisms employed at the front. The operation of this camera was semi-automatic, the operator having nothing to do to keep the camera at work except press the shutter-release. The operating power was derived from a small windmill or air propeller driven by the rush of air past the plane. The automatic mechanism changed the plate and set the shutter after each exposure. Because of the shortage of long-focus lenses, these cameras were constructed to use lenses of 8-inch to 12-inch focus, and the English 4 by 5 plate. Some 750 of these cameras were constructed. They played an indispensable part in the training of nearly 3,000 aërial photographers in this country. They were also used by our bombing squadrons at the front.

At the same time it was generally agreed that we ought to plan to follow the French practice as soon as lenses of greater focal length could be manufactured in this country. Increase in focal length was becoming imperative, because aërial photographers were being compelled to make exposures from much greater heights than in the earlier part of the war. (For the benefit of those unacquainted with photography, it is noted here that lenses of short focal lengths will not record the details of objects a great distance away from the camera,

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the longer-focus, rarer, and more expensive lenses being required for distance work.) As a basis for the design of cameras of longer focus, a sample of the 20-inch-focus camera used by the French had been sent to this country by the American Expeditionary Forces. The first camera of this focal length authorized was similar in general construction to this French camera. It was designed on the unit system, each part—shutter, camera body, lens cone, and magazine—being of standardized dimensions. It was understood that these standard dimensions were to be followed in all subsequent cameras, both in this country and in the countries of the Allies.

The ideal constantly kept before all designers of aërial cameras had been the completely automatic type, in the use of which the observer or pilot would have a minimum of work. Late in 1917 the Photographic Section of the Air Service, American Expeditionary Forces, secured the rights for the manufacture of an ingenious design of automatic plate camera, invented by Lieutenant DeRam, of the French Army, and requested that it be put in production. In this camera the magazine, which carried fifty plates, each 18 by 24 centimeters in size, rotated after each exposure, and the exposed plate was removed from the front of the pile and carried to the back. After some study here of the incomplete model, this camera was redesigned in such form as to fit it for methods of American manufacture. It was made semi-automatic in operation; that is, the work of the observer or pilot consisted merely in releasing the shutter at will, a fresh plate always being in place. At the time of the armistice, 200 of these cameras were rapidly approaching completion.

Meanwhile, experiments in the utilization of film were actively pushed. Various difficulties and problems had to be solved before film could be considered practicable. Considerable time was consumed in overcoming the peculiar static electrical discharges which occur on film in cold, dry regions, such as in high mountains or the upper atmosphere, and fog the sensitive surface by their light. The film camera finally decided upon was based on a fundamental design by the

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Folmer & Schwing organization of the Eastman Kodak Company. This camera, known as the "K" type, carried a film on which 100 exposures, 18 by 24 centimeters in dimension, could be made at one loading. The film was held flat by an ingenious device. The film strip passed over a flat perforated sheet behind which a partial vacuum was set up by a suction, or Venturi, tube extending outside the body of the airplane. The camera was entirely automatic, and was driven either by a wind turbine of adjustable aperture or, in war planes, by electric current from the heating and lighting circuit. The observer in the airplane needed only to start the camera and regulate its speed according to the speed with which the airplane was passing over the ground below, and the camera thereafter would of itself take pictures at such intervals as to map completely the terrain under observation.

In conjunction with the use of film in cameras there arose the problem of how to handle the film in the dark room during the ordinary manipulations of developing, fixing, washing, and drying—a serious problem when the large dimensions of the film and the difficulty of handling it were taken into consideration. This problem was attacked and a film-developing, -handling, and -drying machine was produced.

Some 200 of these automatic film cameras were on order at the close of the war. Altogether, over 1,100 airplane cameras of all types had been, or were about to be, delivered when the armistice came. These were built by the Eastman Kodak Company, Rochester; the Burke & James Company, Chicago; the G. E. M. Engineering Company, Philadelphia; and Arthur Brock, Jr., Philadelphia.

One of the most serious problems in aërial photography was the proper mounting of the camera in the plane. Not only does the plane travel at a speed which prescribes exceedingly short exposures and therefore highly sensitive photographic materials, but also the motor causes a continuous vibration, which, communicated to the camera itself, would be fatal to the desired sharpness in the negatives. The experimenters of the Air Service carried out a long, extensive, and most interesting

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investigation at Langley Field to clarify the whole question of preventing the vibration of the airplane camera. The first task of the scientists was to work out a method of making the camera itself record the vibrations communicated to it by the plane when the box was not held by a proper vibration-neutralizing suspension. The plan adopted was to send up a camera, so mounted on an airplane, focus it on a light on the ground below, open the shutter, and take a time exposure from the swiftly flying plane. The result, of course, was a streak, or trail, written on the plate by the point of light below, the jagged or wavy composition of this trail indicating the vibrations of the camera and, inferentially, determining the proper principles of a suitable mounting. The first thought was to do this work at night, as the British had done, when the light below would pierce the darkness distinctly. But night flying is hazardous, and a better plan was called for. Nor would the proposal to use an extremely strong light in broad daylight do, because, though the light would indeed be photographed continuously across the plate, so also would the surrounding ground, and the general result would be a fogging or blurring of the outlines of the streak. The problem was finally solved by conducting the experimental work over woodland in the late afternoon. A strong reddish light was so placed in the wood as to be visible from above. The surrounding green foliage supplied a frame of sufficient contrast to the light to make its impression distinct on the plate. To emphasize the contrast, the camera lens was covered with a reddish-colored ray filter which brought out sharply the outline of the streak. These tests resulted in the design and production of new and unique camera mountings which successfully stopped all vibrations.

A problem on which it was necessary to have the closest coöperation of the plane designers was that of installing the large 20-inch-focus cameras in the airplane. There is little room at best in a plane, and the demands for armament, wireless, and bombing space all had to receive attention. In the American service a distinct advance was made in the design of a special plane intended primarily for photographic recon-

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naissance. Several of these planes, which were the most completely equipped for photographic purposes of all those designed during the war, were built, and, except for the armistice, the type would have been put into quantity production in the late fall of 1918.

Parallel with this development of apparatus went studies of the sensitive materials and delicate methods involved in photography from the air. Because of the swift motion of the plane, extremely short exposures were imperative. Therefore the most advanced technique of instantaneous photography had to be applied. The coöperation of various plate manufacturers was obtained, who brought out, especially for the Government, several new plates which proved, on being tested, to be superior to any which had appeared in the war on either side.

As an airplane rises higher and higher in the sky, the moisture of the atmosphere intervening between the machine and the ground creates a haze which makes aërial photography above a certain height unsatisfactory, and even impossible, with the naked lenses as used on the ground. The problem of finding the best means for piercing aërial haze occupied the attention of a corps of experts, working both in the laboratory and in the field. The solution lay in the use of special color filters, of a prevailingly yellow cast, which obscured the bluish light characteristic of haze. Filters of new materials specially adapted to airplane use were made available as a result of this study.

Field equipment of quite new and special design for performing photographic operations had to be designed and built. Among the most interesting of these developments was the photographic truck or mobile photographic laboratory. This consisted of a specially designed truck and trailer containing all the equipment necessary to the rapid production of prints in the field. The truck body was equipped with a dynamo for furnishing the electrical current required for lights and drying fans; and each unit was provided with an acetylene generator for emergency use if the electrical appara-

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tus should break down. The mobile dark room carried on the trailer of each unit was equipped with tanks, enlarging camera, printing boxes, and other necessary apparatus. In all, some seventy-five of these field laboratories were constructed.

The development of new apparatus and new materials was, from a popular standpoint, in many ways the most interesting phase of the work of the photographic scientists. At the same time it should be remembered that the great problem in this field of American endeavor, as in all the other fields, was to produce the supplies in tremendous quantities. In October, 1918, we shipped overseas 1,500,000 sheets of photographic printing paper, 300,000 dry plates, and 20,000 rolls of film. We also sent twenty tons of photographic chemicals. These were merely the principal items in the consignment. Besides paper, plates, and chemicals, the field force required developing tents, trays, printing machines, stereoscopes, and traveling dark rooms, to name only some of the principal items. Much of the material already on the market was not suitable for the purpose, and the production of specially manufactured supplies was therefore necessary.

THE FIREWORKS OF FLYING

It is interesting to consider that without fireworks, and particularly without some of the familiar forms of them used to celebrate the Fourth of July, war flying would have lost much of its efficiency. Night flying would have been well-nigh impossible, and even day flying would have had to invent substitutes for fireworks had they not been available.

The squadron fields near the front were kept as dark as possible at night, for obvious reasons. The first inkling that a squadron commander might have of the approach of one of his aviators at night would be the sudden appearance, high in the air, of a green or red or white Roman-candle ball. This was the signal enquiring if the landing field were clear. A pyrotechnic star of a predetermined color, shot from the ground, would answer the homing birdman; and, if the signal were affirmative, he would descend through the sheer blackness,

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unable to see clearly, yet confident that he should make his landing safely. As the plane neared the ground, under one of the wings a flare of dazzling power would suddenly begin to burn, for a few seconds flooding the field with light. In that brief space of time the plane would have made its landing, and soon field and quarters would again be obscured under the protecting blanket of darkness.

Every service airplane at the front was equipped with one or more signaling pistols. In appearance these weapons were more murderous than the "gat" carried by a desperado of the movies, but, like the prize bulldog with the undershot jaw, they were more deadly in looks than in deeds. Their formidable cartridges were larger than the shells used in shotguns, which they resembled almost identically in appearance; but every one of them contained only a Roman-candle star and a sufficient charge of powder to eject it a good distance into the air. The sound of the discharge was a mere whisper of the shattering roar that might be expected from so redoubtable a piece of ordnance. These aviation pistols were similar to the Very signal pistols used in the trenches. The stars shot were of three colors, red, green, and white, and the color of a cartridge's star was painted on the end of the shell. This base was also ridged with a different pattern for each color, so that at night the aviator could, by feeling with his fingers, tell the color of the cartridge without seeing it. Codes of numerous messages were worked out in different combinations of these three colors. The stars were easily visible in broad daylight, too, and were used for many signaling purposes. They indicated the position of enemy troops or the presence of hostile aircraft, they called for help from other airplanes, and they signaled squadron orders when the machines were flying in formation.

But the signal pistol had a more sinister use. If the pilot were driven down in enemy territory, it became his duty to destroy his machine. Sometimes the signal pistol was used effectively to set airplanes on fire under such conditions. The pilot had only to open his gasoline tank and fire a Roman-candle ball into the escaping fluid. In other instances when the

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aviator landed amid enemy troops, he was able to hold them at bay with his signal pistol until his plane was burned beyond the possibility of salvage. We manufactured Very pistols in this country; but all those actually used by our fliers in France were purchased abroad.

Night flying was one of the most hazardous duties of the aviator, principally because of the danger involved in landing. The fields well behind the front were usually brightly illuminated by flood lights at night, but as a rule those nearer the enemy were left in darkness to protect them from the attacks of hostile aircraft. The aviator can usually see the ground faintly at night, but he is unable to make an accurate judgment of the distance of his machine above the ground. This danger was greatly alleviated when the wing-tip flares were invented. The wing-tip flare consisted of a small cylinder of magnesic substance in a metallic holder, one flare being fitted under each lower wing of the plane. Each flare was controlled by a push button in the pilot's cockpit. Pressure on the button sent an electric spark into the magnesium and touched it off. When the descending pilot judged that he was near the ground, he pushed one of the buttons. Immediately the flare ignited and burned for about fifty seconds with the brilliant light of 20,000 candle power. Being hidden by the wing, this light did not dazzle the eyes of the aviator, but the reflection from the under surface of the wing lighted up the field for an adequate distance in all directions.

Another important use of pyrotechnics occurred in those enterprises known as night-bombing raids. Since both sides kept their vulnerable ammunition dumps and important buildings completely unlighted at night, hits from bombs dropped from aloft were almost accidental, even though the night raider knew that he was in the general vicinity of his objective. To enable the night bomber to see his target, the interesting piece of pyrotechnics known as the airplane flare was invented. This was a great charge of magnesium light held in a cylindrical sheet-iron case nearly four feet long and half a foot in diameter, the exact dimensions being 46 by 5 inches.

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The flare weighed thirty-two pounds. Within the cylinder was not only the magnesium stick, but also a silk parachute twenty feet in diameter. The entire cartridge was attached to the airplane by a release mechanism similar to that which held a drop bomb. The pilot or observer, when over his objective, touched a button, and the entire cartridge, iron case and all, dropped from the plane. A pin wheel on the lower end of the case was spun by the rush of air, and the resultant power not only ignited the magnesium, but at the same time detonated a charge of black powder sufficient in force to eject the flare and its tightly rolled parachute from the case. The parachute immediately opened; and the burning flare descended slowly, flooding a large area of the ground below with a light of 320,000 candle power, this light burning for about ten minutes. Such a light not only enabled the bomber to drop his destructive missiles accurately, but it was found by experience that it also dazzled the eyes of anti-aircraft gunners below and made their aim inaccurate. The light of this flare was so strong that it was possible for the airplane above to obtain photographs of good detail on the darkest of nights.

We were just starting to produce these flares when the war ended. The actual production of pyrotechnic supplies in this country was in fact small, the American Expeditionary Forces depending almost exclusively for these supplies upon French and British sources.

KEEPING OUR FLIERS WARM

When the commander of an airplane squadron sends an aviator into the high altitudes, he sends him into a climate which, much of the year, is colder and more severe than any known on earth, even at the North Pole. Not only is the temperature of the air likely to be many degrees below zero at the heights which war planes attained, but the flier must face this bitter cold in a gale of wind that is never blowing less than a hundred miles an hour. When we trained a corps of aviators to fly at altitudes of 18,000 to 20,000 feet above the western front, it was necessary, therefore, for us to design and

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manufacture for them the warmest clothing ever made. They were dressed more warmly than any polar exploration party that ever set forth; more warmly, in fact, than any other class of men in the world. For we not only gave them the protection of all the fine wool, leather, and fur that they could wear without hindering their movements, but in addition we literally wrapped them in flexible electric heaters.

The first purchases of aviators' flying clothes were made by the coördinated action of the Council of National Defense and the Quartermaster's Department. It was soon apparent that the design of such clothing was a special matter which the aviation authorities themselves should control, and purchases thereafter were all made by the Bureau of Aircraft Production. There were no standard styles at the time, and it became necessary for us to develop our own equipment. This development resulted in an output for the flier that became standard.

In moderate weather the flier wore upon his head a woolen hood, or helmet, extending well down over the forehead to the eyes, and around the neck to the shoulders. In cold weather, or for high-flight work, this headgear was augmented by a silk helmet of double thickness, containing between its layers an electrically heated pad connected by copper wire with the electric generator on the plane's engine. Outside this was worn a soft leather helmet lined with fur, extending down over the back of the head, covering the ears and cheeks, and fastening under the chin. Then the face was entirely covered with a leather face mask lined with wool and having an opening for the eyes, over which were worn a pair of goggles. When the pilot was also required to operate the radio system, in place of the fur-lined helmet he wore the radio helmet. This was of leather, and it resembled the other in appearance; but it contained the receiver of the wireless telephone, which enabled the flier to hear what was spoken to him in an ordinary tone of voice several miles away. In addition to this equipment, the aviator who went up to the great heights wore the oxygen mask. This was of rubber. Besides supplying oxygen, it con-

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Photo from McCord & Company

WELDING NOSE CASTINGS ON DROP BOMBS

Photo from Ordnance Department

1,000-POUND AND 550-POUND AIRPLANE BOMBS

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Photo by Signal Corps

OXYGEN HELMET WITH TELEPHONE ATTACHMENT

Photo from Marlin-Rockwell Corporation

INSPECTING AIRPLANE DROP BOMBS

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tained a transmitter which allowed him to speak as well as to hear by wireless.

Over the body was worn a one-piece flying suit extending from the feet to the throat, belted and buttoned tight at the ankles and wrists. The outer material of this suit was waterproof, and when it was buttoned on there were no gaps through which the air could penetrate. This suit was lined throughout with fur. It was a considerable problem to find a fur of extreme warmth with a pelt strong enough to withstand rough usage and still not be too great in bulk, and purchasable withal at a price not too extravagant. After the furs of many beasts had been examined and tested, it was determined that the hide and fur of a Chinese Niuchwang dog met these requirements better than any other. We were making so many of these suits that we required all the dogskins we could get, not only in this country, but in China. Merely the one final purchase of these pelts before the armistice was signed was of nearly 500,000 of them. Half a million dogs in an interior Manchurian province gave up their lives that the American aviation warfare might succeed.

It might seem that such a garment, with its waterproof outer surface and its furry lining, would be warm enough for any work. But the aircraft authorities of the United States were not content until they had installed, between the fur and the outer covering, thin, flexible electric-heat units connected by silk-covered wire with the dynamo on the engine. Similar heating pads were placed in the gloves and moccasins of the fliers.

On their hands, besides the electrically heated gloves, the fliers wore gauntlets of muskrat fur extending well up the arms. These gauntlets were of a special design which allowed the fingers of each glove either to remain in a fur-lined pocket or to be withdrawn from the pocket without removing the gloves from the hand. Over the electrically heated moccasins were worn leather moccasins extending well up the calf of the leg and lined with heavy sheep wool. These were fastened with straps and buckles. Thus clad, our aviators were acknowl-

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edged generally to be the most warmly and efficiently equipped of any at the front.

Besides these special garments for warmth, the fliers required many other items of clothing, such as sweaters, leather coats, fur-lined coats, helmets, and many styles of goggles.

The total cost of air clothing, provided or in course of manufacture on November 11, 1918, was over $5,000,000. Some of the major items, in round numbers, were 50,000 fur-lined flying suits (at $36.25), 100,000 leather helmets, an equal number of leather coats costing from $10 to $30 each, and over 80,000 pairs of goggles at $3.50 apiece.

PROTECTION IN HIGH ALTITUDE FLYING

The veteran of the air squadron scoffed at the new-fangled outfits of oxygen masks and tanks which were carried in an experimental way on some of the high-flying planes at the western front when hostilities ceased. Nevertheless, had the war continued a few months longer it is probably true that the oxygen apparatus would have been included in the indispensable equipment of every airplane in the front areas. Such a development, had it occurred, would have been due largely to the efforts of the American Air Service. Many aviators who went into high altitudes, fought there, and lived to tell about it, doubt the necessity of oxygen-supplying apparatus, since they themselves returned safely without it. But the experiments conducted by the Bureau of Aircraft Production demonstrated conclusively that the flier artificially supplied with oxygen in the high altitudes is much more efficient than the one who is without it.

These experiments were conducted in a room which duplicated the conditions of high altitudes. At 19,000 feet the pressure of the atmosphere is one-half the atmospheric pressure at sea level. The lack of pressure in itself causes no appreciable physical or mental reaction; but the reduced pressure at 19,000 feet means that in a given amount of air there is only one-half the oxygen that there is in a similar amount at sea level. The lack of oxygen is serious. Experienced aviators were

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placed in an air-tight chamber under the observation of government scientists. The air in this chamber was then exhausted until it corresponded to the atmosphere at the 19,000-foot level. The subjects were then set at small mechanical tests, such as the pushing of certain buttons when different colored lights were turned on, these tasks requiring a degree of mental concentration. In this and similar tests it was discovered that not only do the subjects lose accuracy in the attenuated air, but their movements become conspicuously slower. In the parlance of the pilot, they become "dopey." More than one aviator, returning from a high altitude, confessed to this feeling.

When the British analyzed their air casualties during the first year of the war, they found that two of each 100 fliers in the casualty list were killed or hurt by the enemy, eight owed their misfortune to defects in the planes, and the other ninety came to the hospital or the grave because of themselves—their carelessness or recklessness, their physical failings, and all other conditions which may be summed up as part of the human equation. A thorough study on the part of the British disclosed that practically all the flying *personnel* was suffering from what became known as oxygen fatigue, caused by flying so many hours each day in altitudes where there was not enough oxygen to feed the body properly.

Before the war broke out the aviation record was 26,246 feet above sea level. In January, 1919, this record had been lifted nearly a mile, to 30,500 feet. Early in the war, pilots at the 7,000-foot level could laugh at anti-aircraft fire, and few machines ever went above 10,000 feet. With the first equipment the "ceiling"—that is, the average high level to which everyday flying goes—was about 12,000 feet. When the war closed, a pilot was not safe under the 15,000-foot level, thanks to the development of anti-aircraft guns, and the safest machine had become that which could fly highest. The aviators were demanding a working ceiling of 18,000 feet, and were obtaining it, too, from the latest type of planes. It was evident that the reduced oxygen at this ceiling was re-

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sponsible for casualties among the fliers; and we could expect the ceiling to be pushed even higher as anti-aircraft guns became more powerful. The need of oxygen equipment was plainly indicated. Even at 18,000 feet, the aviator who relied upon the normal oxygen supply at that altitude, though he might feel perfectly fit, was actually slower in judging distances, aiming his guns, firing them, and maneuvering his plane.

The first oxygen apparatus was designed for the British air service and was made at the plant of De Lestang in Paris. The demand for the apparatus was so great that an automobile was constantly kept waiting at the factory, so that each set, as soon as it was finished, could be rushed straight to the front. The first British squadron which used oxygen equipment reported that its men gave six times the service given by any other British squadron.

Our Air Service adopted the Dreyer oxygen apparatus, which was the original device produced by the British. We found it to be a handmade appliance, but under our direction we adapted it to American methods of manufacture. The British apparatus was built to supply oxygen to one man only. We changed it to take care of two men. The model received was too heavy; we reduced the weight. Finally we added improvements to make it more efficient and reliable and redesigned it to meet American factory methods.

Such an equipment has to be entirely automatic in its operation and as reliable as human ingenuity can make it. The Dreyer device embodies several instruments, all of which must work perfectly under widely varying conditions. In use its tanks will contain oxygen under pressure ranging from 100 pounds to 2,250 pounds to the square inch; yet the mechanism must deliver the oxygen to the aviator at a constant rate, regardless of its tank pressure. Then the whole apparatus is subjected to temperatures that may be as high as 80 degrees above zero or as low as 30 degrees below. It must function evenly in the atmospheric pressure at any altitude up to 30,000 feet, delivering more oxygen as the atmosphere thins.

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Such was the problem of manufacture. Yet, taking up the work in January, 1918, we turned out six complete equipments by May 3, 1918, sending them overseas by special messenger for actual test on the front. Twenty-eight days later we shipped 200 sets. By the end of the war we had built 5,000 complete oxygen equipments. Of this number, 3,600 had been sent to ports of embarkation awaiting shipment, and over 2,300 of these had been shipped overseas. In October we had reached a production rate of 1,000 sets a month.

Some of the difficulties of this production may be read in the description of the complicated make-up of the apparatus. The equipment consisted of a small tank or tanks, the pressure apparatus, the tube leading from the reservoir, and, finally, the face mask covering the mouth and nose. This mask had combined with it either the interphone, a mechanism which cut off the roar of the engine from the ears of the passengers and allowed the pilot and observer to talk freely with each other, or, in certain instances, the receiver of the radio telephone or telegraph. The flow-regulating apparatus consisted of five parts. In front of the pilot was a high-pressure gauge to indicate the supply of oxygen in the tank. In the tank was a high-pressure valve with an upper chamber which compensated for the temperature. There was also a shut-off valve, hand operated, which could be set to provide a flow of oxygen to one man, to two men, or to none at all. Then there was a regulating valve, operated by an aneroid barometer, which adjusted the oxygen flow to the altitude, the flow increasing as the machine went higher. Finally, in the pilot's view there was a flow indicator consisting of a small fan wheel which told the aviator that the oxygen was actually flowing. The mask presented a difficult problem, for it must be big enough to contain the radio receivers and yet small enough to enable the aviator to see and work. And it had to keep its adjustment in a gale of at least a hundred miles an hour.

The actual use of the equipment on the front was just starting when the armistice was signed. We sent across to France a special division of experts to take charge of the installation

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of this equipment on the planes. At the close of hostilities we required all military planes flying above an altitude of 10,000 feet to be equipped with oxygen apparatus. This class included day-bombing, pursuit, and *chasse* planes, a certain number of night-bombing planes, and army and corps observation planes.

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CHAPTER XXI

THE AIRPLANE RADIO TELEPHONE

ELECTRICAL science was called upon to furnish veritable marvels and prodigies during the recent war as aids to the American arms, but in no respect did it respond in more successful and spectacular fashion than when asked to produce a wireless telephone system that would make possible the transmission of human speech to and from moving airplanes. It is doubtful if any other branch of science enlisted for war work produced an instrument or mechanism so far in advance of what was known before the war as was the airplane wireless telephone in its class.

To be sure, we had the radio telephone some time before America entered the war, and even before the war broke out in Europe in 1914. Ever since the scientists had begun experimenting with wireless electricity it had been axiomatic that, at least theoretically, whatever you can do with wires you can do without wires. Following the development of the wireless telegraph came the production of the wireless telephone; and the invention had been so perfected in 1915 and 1916 that in the United States Navy's official test at the Arlington Station, across the Potomac River from Washington, human speech sent out by the transmitters there was heard simultaneously at the Eiffel Tower in Paris and at the Government's own wireless station in Hawaii.

But there is a vast difference between using the wireless telephone in the quiet of the radio rooms aboard ship or in the shore stations, and using it amid the roar of the powerful engine which propels an airplane. The equipment, too, that had been used on the ground was altogether too cumbersome to go into the fuselage of an airplane.

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As early as August, 1910, American genius had successfully accomplished wireless telegraph transmission from airplane to ground, and in October of the same year the idea of commanding a whole aërial fleet by telephone was conceived, and plans for its development were discussed by army officers on duty at the International Aviation Tournament at Belmont Park, Long Island. In 1911 a message was successfully transmitted from an army airplane over a distance of two miles. In 1912 the Signal Corps had increased the distance to fifty miles. Two years later, in the Philippine Islands, a message had been successfully received on an airplane in flight over a distance of six miles.

In 1915 the Aviation Section entered upon a definite plan of development of aircraft wireless at the Signal Corps Aviation School, San Diego, California. This plan was based upon the Belmont Park idea and subsequent discussions, with the voice-commanded tactical air fleet as the ultimate goal. The airplane had changed from the pusher to the tractor type, with the noise of the motor driven back by the blast of the propeller into the face of the aviator. The airplane wireless problem was thus quite completely changed. Under these new conditions the development was nevertheless entered upon, and it was continuous thereafter. In October a spring-driven dictaphone was taken into the air and a record of speech made in the noise of the motor. This was contemporaneous with the successful long-range experiments in radio telephony at Arlington, referred to above. A study of this dictaphone record convinced the aviation officers that the radio telephone for airplanes was entirely practicable. Experiments during the fall and winter with various means of driving the wireless power plant resulted in a decision to develop the air fan as a source of power, rather than the gear or belt system.

This development continuing through 1916, transmission by telegraph from airplane was accomplished up to 140 miles, means for receiving in the noise of the motor were worked out, and a message was successfully telegraphed between airplanes in flight. The radio telephone was under construction, and in

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February, 1917, the voice was first transmitted by telephone from airplane to ground. Like Alexander Graham Bell's first wire telephone, the apparatus was crude. But the door was unlocked and ready to be opened upon new progress.

When, on May 22, 1917, General Squier, the Chief Signal Officer of the Army, called upon the scientists to develop at once an airplane telephone, he was not only introducing them into what was to many of them a new field, but he was asking them to produce what the science of Europe had been unable to create in nearly three full years of acquaintance with the successful ground system, although the needs of airplane fighting demanded this invention as they demanded almost nothing else.

It will be seen that, when we began this development as a war measure, we had a considerable basis of experience to work upon. The Army had established the foundation of operation on the airplane, had made a study of the tactical requirements, and knew what it wanted. The Western Electric Company, in 1914 and 1915, had conducted extensive experiments with the radio wireless telephone at a ground station at Montauk, Long Island, and had played an important part in the long-range experiments at the Arlington station. There had been wireless voice communication before this time, but the apparatus and systems perfected at Montauk set the standard on which all subsequent development was built. The French Scientific Mission and other officers of the Allies had arrived and enabled us to check up what had been done abroad and to confirm or modify our ideas of the tactical requirements.

At the conference with General Squier in May were Colonel Rees of the Royal Air Force of Great Britain; Colonel C. C. Culver, United States Army, then a captain; and F. B. Jewett and E. B. Craft, respectively the chief engineer and the assistant chief engineer of the Western Electric Company. At this meeting General Squier outlined the future part which the airplane was to play in the war and pointed out how invaluable would be a successful means of communication between battle planes when flying in squadron formation. Mr.

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Jewett, who had received his commission as a major in the Signal Corps, was ordered to take charge of the work of developing radio communication for aircraft. Captain Culver had taken part in the 1910 experiments and discussions, and since 1915 had been conducting the army development of airplane wireless at the aviation school at San Diego, California. He was detailed to work with Major Jewett and his engineers, bringing to their assistance the result of his experience and the point of view of the trained military man and the aviator.

The first development was carried on in the laboratories of the Western Electric Company on West Street, in New York. Men and materials were drafted from every department of the Company, and the laboratories were soon seething with activity. In a few weeks the first makeshift apparatus was assembled, and the first practical test of a radio phone on an airplane was made at Langley Field at Hampton, Virginia, less than six weeks after the Signal Corps had given the go-ahead. Three employees of the Western Electric Company on that day established telephone communication between an airplane in flight and the ground. A few days later the first apparatus produced successful communication between planes in the air.

It is not feasible here to go into a technical description of the wireless telephone. The most vital part of the apparatus, and the essential factor in airplane wireless telephone communication, is a vacuum tube containing an incandescent filament, a wire mesh or grid, and a metal plate. By means of electrical current the wire filament is heated to incandescence. The tube has the property of receiving the energy of the direct current of a dynamo and, through the medium of the wireless antennæ, of throwing it out into space as a high-frequency alternating current. Such is the sending tube. A modification of the same tube picks up from the antennæ the high-frequency alternating vibrations from some other sending apparatus and transforms them into direct current, which carries the sound waves of the human voice along with it.

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The design of the radio apparatus itself was relatively simple for the experts who had undertaken the work, for the company had already developed some highly successful forms of vacuum tubes, and it was an easy matter for these technicians to assemble tubes with the necessary coils, condensers, and other apparatus of the transmitting and receiving elements, and produce a system of so small compass that it could be carried on an airplane. But working this apparatus under ordinary conditions in the quiet laboratories and in a swiftly moving and tremendously noisy airplane were two different propositions.

One of the first problems was to design a comfortable head set which would exclude all undesirable noises and admit only the telephone talk. A form of helmet was finally devised with telephone receivers inserted to fit the ears of the pilot or observer. Cushions and pads adjusted the receivers to the ears, and the helmet fitted close to the face so as to prevent as far as possible the transmission of undesirable sounds, either through the ear passages or through the bony structure of the head, which acts as a sort of sounding board. The designers finally developed a helmet that solved this portion of the problem.

Not only was it necessary to exclude the roar of the engine and the rattle of the machine gun from the ears of the men receiving the radio communication, but it was also necessary to filter out these sounds from the telephone transmitter. Every person who has ever shouted into a telephone knows how sensitive the ordinary telephone transmitter is to extraneous noises. It requires no wide stretch of the imagination to hear in fancy how an ordinary transmitter would behave when beside the exhaust of a 400-horsepower Liberty engine. A brilliant sequence of experimentation conducted by one of the scientists at the laboratory resulted in a telephone transmitter or microphone which possessed the extraordinary quality of being insensitive to engine and wind noises and at the same time highly responsive to the tones of the human voice.

With the receiver and the transmitter perfected, the scien-

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tists thought that the problem of airplane telephoning was solved; but three months of hard work were required before the entire system could be adjusted and put in such shape that it might be considered a practical device for everyday use.

The question of weight was of utmost importance; and a structure that would adequately house and protect the delicate parts of the mechanism from the vibrations and jars of flying and landing, and at the same time not be too heavy for practical use on the plane, was a difficult problem in mechanical design. Day after day the inventors took the mechanism up in flying machines; and night after night they brought it back for more work in the laboratory.

But this was a period of rapid progress. Officials who appeared on Langley Field from time to time witnessed informal demonstrations of the development. In August Mr. Baker, Secretary of War, and General Scott, Chief of Staff, listened to a conversation being carried on in the air, and some six weeks later Brigadier General Foulois witnessed a similar demonstration and from the ground directed the movements of the airplane in flight. The experimental apparatus had reached such a state of efficiency that on October 16, at Langley Field, communication by voice was carried on between airplanes in flight twenty-five miles apart, and from airplane to ground over a distance of forty-five miles. By September, cables had been sent abroad telling of the progress made in this country in the development of the apparatus. Our officers abroad were skeptical and could not believe that this country had outdistanced the scientists of the Allies, who had had three years of war experience to draw upon. By October the designers had brought the system to a degree of perfection where they were willing to risk its use in actual war flying; and Colonel Culver took to the American Expeditionary Forces in France several trunkloads of the apparatus to acquaint those abroad with what had been done and to test the apparatus under service conditions. Meanwhile the development work continued in this country.

Early in December the operation of the apparatus was

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exhibited in an official test at the Morraine Flying Field at Dayton, Ohio. A large number of military and civilian officials, not only of our own country, but also of the Allies, had been invited to witness this test. It must be remembered that at this time even those who had heard about the progress being made were skeptical about the successful adaptation of the radio telephone to airplane work. The designers of aircraft never look with favor upon additional equipment which may clutter up the machine with trailing wires and the like, and possibly compel alterations in standard lines. The pilots, also, do not usually give a friendly reception to new equipment for their planes. The exhibitors at Dayton planned to have two planes in the air at once, so that the officials might listen in on their conversation at a ground station located on the top of a hill near the flying field. By hard work the inventors got their equipment installed, and just at dark on the evening before the day of the trial one machine equipped with wireless went up into the air and held successful communication with the ground. The next morning when the official party arrived, the members viewed the apparatus in the planes while the inventors explained what it was expected to do. The visitors were then conducted to the station on the hill, where those who were putting on the show had rigged up a megaphone attached to the wireless receiver, so that everyone could hear without putting on a head set. The attitude of some of the officials, particularly those from the foreign nations who had had experience in war flying, was skeptical, if not bored. The planes left the ground, and when the machines had gone up so high that they were but specks in the sky, the receiver began emitting the premonitory noises which indicated that the men in the planes were getting ready to perform. Suddenly, out of the horn of the loud-speaking receiver came the words: "Hello, ground station! This is plane No. 1 speaking. Do you get me all right?" Looks of amazement came over the faces of all those who had never heard the wireless telephone in operation before. Soon came the signal from plane No. 2, and then the demonstration was on. Under command from the ground, the

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planes were maneuvered over much of that part of the country. They were sent on scouting expeditions and reported what they saw as they traveled through the air. Continuous conversation was carried on, and finally, upon command, the planes came back out of space and landed as directed.

From that moment there was nothing but enthusiasm in all quarters for the radiophone upon airplanes. It was no longer a question whether the device would work or was any good: it was a question of how soon the company could start manufacture and in what quantities the device could be produced.

The demonstrations which Colonel Culver had been conducting in France began, too, to bear fruit. Both the British and the French had developed experimental apparatus by this time, and this was examined and tested. Then cablegrams began to arrive from abroad requisitioning the American apparatus in large quantities—convincing evidence that it had greater promise than any other.

But still difficulties were ahead, for at this stage the wireless telephone consisted of a few experimental parts built by hand. It remained a heavy task to standardize the equipment and perfect the multitude of designs and drawings that must be in existence before quantity manufacture could begin. All sorts of mechanical details slighted in the experimenting and taken care of by makeshift devices had to be worked out as practical manufacturing undertakings. It was another case of day-and-night work to put the mechanism into condition for production. The factory of the Western Electric Company is in Chicago, but its drafting rooms and laboratories are in New York. As soon as any detail was finally worked out, the drawings were taken by messengers and rushed to Chicago, where the work of producing the manufacturing tools had begun. Only the fastest passenger trains between New York and Chicago were patronized in this part of the development.

As every detail was perfected it had to be checked by actual test in the field; so the company's engineers were almost constantly in the air. One of these experts made 302 flights him-

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self; and 690 flights, of a combined duration of 484 hours, were required in the experimental stage of the mechanism.

Immediately after the official trial in December the Government ordered thousands of sets of the radio telephone. In spite of the enormous detail involved in making ready for production, the first systems were turned out early in 1918, well ahead of the delivery of the airplanes in which they were to be used.

All through this development the designers had to confine their activities within limits set by the producers of the aircraft. This in itself created some puzzling problems. For instance, a constant current of electricity must be supplied to heat the filaments of the vacuum tubes and to operate the transmitter. A simple way to provide this current would seem to be to connect a dynamo with the driving shaft of the airplane engine; but the airplane constructors would not allow any such connection with the engine. Current could be supplied from storage batteries, but the planes were already loaded down with all the gear they could carry, and the use of heavy batteries was out of the question. Therefore it was the task of the telephone designers to supply a dynamo plant that would not add appreciably to the weight of the plane. This was done by installing on the outside of the plane a wind propeller which, driven by the rushing air, had power enough to turn the dynamo. The dynamo must deliver a constant and unvarying voltage to the radio phone if its operation were to be possible; yet a wind propeller on the airplane would be driven by air rushing by at speeds varying from 90 or 100 to 160 miles an hour, the latter figure being the speed of a diving plane. This meant that the wind propeller, and hence the armature of the dynamo, would revolve at a speed varying from 4,000 to 14,000 revolutions a minute. It would seem to be impossible to procure current at a constant rate from a dynamo varying so widely in its speed of operation; yet one of the experts engaged in this enterprise solved the problem, and the dynamo thereafter performed always in a most steady-going and dependable manner.

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Incidentally and as a sort of by-product of the undertaking, the special transmitter and helmet might be employed as a means of communication between the pilot and the observer in a two-seated machine. When the helmet was used for this purpose, the wireless was not employed at all, but the head sets were connected by wires, so that, although one could not hear oneself talk because of the noise of the plane, the pilot and observer could converse over the telephone with ease. Then, by throwing a switch, they could at any time connect themselves with the radio apparatus and talk with the men in another plane three or four miles away or to their squadron headquarters on the ground.

One good result of the airplane telephone was to speed up the training of aviators in this country and to make that training safer. But the primary object was to make it possible for the leader of an air squadron at the front to control the movements of his men in the air. For this purpose extra long range was not required, and the distance over which the machines could talk was purposely limited to two or three miles so that the enemy could not overhear the conversation except when the planes were actually engaged in fighting each other.

The Navy made use of the wireless telephone sets in the seaplanes, and here the range of the equipment was made greater. The Navy also adopted a modified form of the set for the 110-foot submarine chasers. These vessels hunted the submarines in packs, and by means of the radio telephone the commanders of the boats kept in constant touch with each other, thereby greatly increasing the effectiveness of their operations.

Altogether there were produced for the army airplanes about 3,000 combined transmitting and receiving sets of the radio telephone and about 6,500 receiving sets alone.

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Photo by Signal Corps

AVIATORS WEARING TELEPHONE HEAD SETS

Photo by Signal Corps

AIRPLANE RADIO TELEPHONE SET

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Photo from B. F. Goodrich Company

WOMEN WORKERS IN WAR BALLOON FACTORY

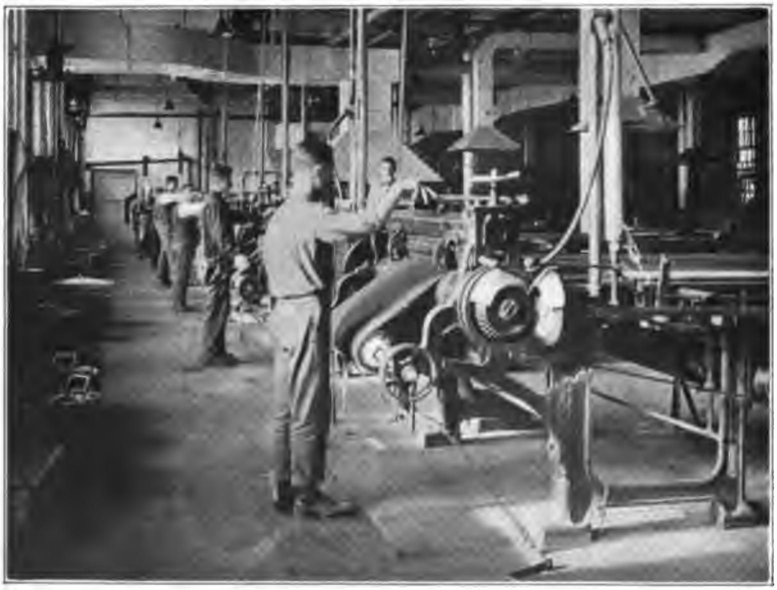

Photo from Air Service

RUBBERIZING BALLOON CLOTH

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CHAPTER XXII

BALLOONS

WHEN, in November, 1782, Jacques Étienne Montgolfier and his brother Joseph sent a sheep, a rooster, and a duck into the sky, lifted by a paper bag inflated with hot air, these Columbuses of ballooning could scarcely foresee the importance which their invention was to have in the great war a hundred and thirty-five years later. To the humble observation balloon in France, rather than to his dashing cousin, the airplane, must go the chief credit for that marvelous accuracy which long-range artillery attained during the great struggle. The balloon itself was spectacular enough, once its true character was known. The fact that the American production of observation balloons during our nineteen months as a belligerent was a complete and unqualified success makes the story of ballooning in France of particular interest to the American reader.

After the animals of the Montgolfier barnyard had made their ascent, two friends of the brothers, M. Pilatre de Rozier and Girond de Villette, essayed to be the first human beings to take an aërial flight. They ascended to a height of 300 feet and returned to earth sound of limb and body. Thereafter and until the World War in Europe, the balloon remained the awe of the circus and country fair grounds and the delight of the handful of sportsmen who took up the adventurous pursuit; but, except for a limited use of captive balloons in our Civil War and in the siege of Paris, in 1870 and 1871, the balloon had no important military use.

The hot-air balloon never could have become of great value to armies. In the first place, it would descend when the balloon cooled off. This defect was overcome by the use of lighter-than-

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air gas. Moreover, the free balloon was subject to the whims of the breezes. To overcome this characteristic, the balloon must be fastened by a cable or propelled by a portable engine. It was obvious, of course, to military experts that a stationary observation post anchored thousands of feet in the air would be ideal in war operations; yet, for all this obvious need, until the time of the World War military science had perfected nothing better than the spherical balloon. The spherical, anchored by a cable, bobbed aloft in the gales and zephyrs as a cork does on the ocean waves. Although there had been some experimentation with kite balloons before 1914, it was not until the World War had been in progress for some months that the principles of stream-line shape were applied to the captive balloon; and the kite balloon, the well-known "sausage," made its appearance, to be the target for enemy aërial operations and the chief dependence of its own artillery.

The term "kite balloon" effectively describes the captive observation balloon as we knew it in the war. It rides the air on the end of its cable much in the manner of an ordinary kite, and some of the early "sausages" even flaunted steadying tails such as kites carry. These principles, applied to the captive balloon, gave its observation basket a stability unknown by the pioneer aëronauts under their spherical bags.

In the first stages of the war the artillery relied principally upon airplanes for firing directions. But the airplane observers, though they could locate the targets fairly well, frequently lost touch with their batteries because of the difficulty of sending and receiving wireless or visual signals upon their swiftly moving craft. This disadvantage brought the captive balloon into use, gradually at first, but before the end of the war on a scale which had practically displaced the airplane as a director of gunfire. The balloon came to be the very eye of the artillery, which, thanks to the development of this apparatus, reciprocated with an efficiency beyond anything known before in the history of warfare.

Sitting comfortably aloft, the observer in the kite balloon basket had the whole panorama of his particular station spread

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before him. His powerful glasses could note accurately everything which occurred within a radius of ten miles or more. He was constantly in touch with his batteries by telephone and could not only give by coördinated maps the exact location of the target and the effect of the bursting shell, but also could, and often did, supply most valuable information of enemy troop movements, airplane attacks, and the like. He was a sentinel of the sky with the keen, long-range vision of the hawk. He played a part less spectacular than the scout airplane, with its free and dazzling flights, but his duties were not less important.

Nor did he suffer from ennui during his period aloft. When a kite balloon went up it became the object of alert attention by the enemy, because it was up there on hostile and damaging business. Long-range high-velocity guns turned their muzzles on it, and planes swooped down upon it from dizzy heights, seeking to pass through the barrier of shell from anti-aircraft guns and get an incendiary bullet through the fabric of the gas bag, an eventuality which meant the ignition of the highly inflammable hydrogen gas and the quick destruction of the balloon and perhaps of the luckless occupants of the basket as well, unless they could get away in their parachutes.

Only quick work could save the men in the basket in such an event. From the time the gas leaped into flame until the explosion and fall of the balloon, there was rarely an interval of over fifteen or twenty seconds. The pilot of the airplane could dodge and slip away from the guns, but not so the pilot of the kite balloon, anchored to a windlass from two to five miles behind his own lines. He had to take what was coming to him, for he was without means of defense. He must carry on his scientific calculations unconcernedly and in his spare moments experience the questionable pleasure of watching, on some distant hill, the flash of an enemy gun trained upon him and then of waiting the twenty or thirty seconds until the whizzing messenger reached him, the while he pondered on the accuracy of the enemy gunner's aim.

Although the artillery on both sides paid considerable atten-

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tion to the observation balloons, the fact was that few of them were brought down by direct shell hits. The diving airplane, with its incendiary bullets, was a far more deadly enemy to the balloon than the ground artillery was. Certain pilots in the various air services made a specialty of hunting "sausages," the nickname given to kite balloons because of their shape. In the seventeen days between October 26 and November 11, 1918, our Army lost twenty-one balloons, of which fifteen were destroyed by enemy planes and six by enemy shell. But it may be noted that our aviators and artillery exacted a toll of fifty German balloons in the same period and on the same front. Of an average hundred balloons lost at the front, sixty-five were destroyed by enemy attacks and thirty-five by natural wear and tear.

The German general staff so highly esteemed the work of the Allied kite balloons that in its system of rating aviators it ranked a balloon brought down as the equal of one and one-half planes.

The average life of a kite balloon on an active sector of the western front was estimated to be about fifteen days. Some of them lived only a few minutes. One American balloon passed unscathed through the whole period of American activity on a busy sector. Ordinarily, five or six months of nonwar service will deteriorate the balloon fabric; but there are many instances of useful service longer than this.

Germany is said to have had, when the war broke out, about a hundred balloons of the kite type. France and England had a few of them. The German balloon was known as the Drachen. Its gas cylinder of rubberized cotton cloth was approximately sixty-five feet long and twenty-seven feet in diameter, the ends being rounded. To give it a kite-like stability in the air, a lobe, which was a tube of rubberized fabric, of a diameter approximately one-third that of the main balloon, was attached to the underbody as a sort of rudder, which curved up around the end of the balloon. This lobe was not filled with gas, but the forward end of it was open, so that when the balloon rose the breeze filled the lobe with air. The inflated

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rudder then held the Drachen in line. The lobe automatically met the emergency. In calm, windless weather the balloon needed no steadying, and the lobe was limp. Let the gale blow, and the lobe inflated and held the nose of the Drachen into the wind. As a further stabilizer three tail cups, with mouths open to the breeze, were attached ten feet apart on a line descending from the rear of the balloon. In a strong wind these helped to keep the contrivance from swinging. The tail cup was made of rubberized fabric, circular in shape, about four feet in diameter, and about two feet deep when inflated by the breeze. It looked like an inverted umbrella, and was attached to the tail end of the balloon for exactly the same reasons that account for the tail attached to a kite.

The Drachen type of balloon was still in the experimental stage here and in France and England when the Germans swept over Belgium. It was clumsy and relatively unstable in high winds; yet its importance to the artillery could not be ignored by the Allies. The results of its work daily became more evident. The first effort of the Allies was to take the Drachen as a model and to improve it by giving it greater stability and capacity for higher altitudes.

While this work was going on, Captain Caquot, of the French Army, produced a kite balloon so superior that it quickly superseded what had been in use. Germany clung to the Drachen for a time, but finally abandoned it for the Caquot principles of design. The earlier balloons of the sausage type had been merely cylinders with hemispherical ends. Now for the first time, in the Caquot model, appeared a captive that was sharply stream lined. Stream lines are lines so curved as to offer the least possible resistance to the medium through which a mobile object, such as a yacht, an automobile, or an airship, moves. The Caquot gas bag was ninety-three feet long, as compared with the Drachen's sixty-five; yet its largest diameter was only twenty-eight feet—only a foot thicker than the pioneer German type. The Caquot, like all balloons developed in the war, was made of rubberized cotton cloth. Its capacity of 37,500 cubic feet of hydrogen gas lifted the mooring cable,

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the basket, two observers, and the mass of necessary equipment, and in good weather the balloon could ascend to a maximum altitude of over 5,000 feet.

The principal innovation in the design of the Caquot balloon was the location of the balloonette or air chamber within the main body of the gas envelope. This chamber was in the forward instead of the rear part of the bag and along the bottom of the envelope. It was separated from the gas chamber by a diaphragm of rubberized cotton cloth, which was sewn, cemented, and taped to the inner envelope somewhat below the "equator" or median line from the nose to the tail of the gas bag. When a balloon of the Caquot type is fully inflated, the diaphragm rests upon the underbody of the gas envelope, and there is no air in the balloonette. Then, as the balloon begins to ascend, at the higher levels the surrounding air pressure is reduced and the gas in the balloon expands. This expansion would normally burst the envelope when the balloon is at a high altitude, except for a safety valve which pops at the danger point and relieves the pressure. Also, when the balloon is anchored it gradually loses gas, for no fabric can be made entirely gas-tight. A flabby balloon in a gale of wind is dangerous to the men in the basket. The flabbiness may be expected to increase, too, as the balloon is hauled down into the heavier air pressures. It was to overcome this flabbiness that the interior balloonette was first invented. The new location of it not only accomplished this end, but also increased the stability, lessened the tension on the cable, and allowed an almost horizontal position of the balloon itself. As the balloon rises, the wind blows into the balloonette through a simple scoop placed under the nose of the balloon. This forces up the diaphragm and compensates for any loss of gas from the envelope above. If the day is calm and no air is driven into the balloonette, there is no danger from the flabby balloon anyhow, and hence no need for the air chamber. The device is automatic.

The Caquot was equipped with lobes of rubberized fabric to act as rudders. These lobes, spaced equidistantly around the

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circumference of the rear third of the balloon, filled with wind when wind was blowing and there was need of rudders. In calm weather the lobes, particularly the two upper ones, hung loosely, resembling elephant ears. On account of this characteristic the Caquots were nicknamed "elephants" by the soldiers.

The Caquot maintained its stability without tail cups, and its construction caused it to ride almost horizontally and directly above its moorings, regardless of winds. In this position it put much less strain on the anchoring cable than the old-fashioned sausage. This balloon has been operated successfully in winds as high as seventy miles an hour; apparently no gale could keep it on the ground.

When we went into the war, both our Army and our Navy were practically without observation balloons, and we knew little about their construction, although we had been watching the developments in Europe. One local National Guard organization had taken to the Mexican border a locally designed captive balloon, the gift of the Goodyear Tire & Rubber Company, of Akron, Ohio. In April, 1917, the total production capacity of the United States was only two or three military observation balloons in a month. But when the emergency came the various concerns whose plants were adaptable to this class of manufacture—the list including the Goodyear and Goodrich organizations at Akron, the United States Rubber Company, the Firestone Tire & Rubber Company, the Connecticut Aircraft Company, and the Knabenshue Manufacturing Company—all joined whole-heartedly with the Signal Corps to solve our balloon problems.

One of these problems was the production of balloon cloth, for which there had never been any commercial call in this country. Such cloth obviously must be of cotton, for in cotton we had our largest supply of textile raw material. The cloth must be closely woven, smooth, and strong, to serve as a base for the rubberizing process. The standard balloon cloth should have a weave of approximately 140 threads to the inch both ways. In our vast cotton industry only a few mills had ever

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made such a cloth, and then only in small quantities. In fact, we found only a few looms in existence capable of weaving the cloth, which must be from thirty-eight to forty-five inches wide. A single loom could turn out only an average of ten yards of this cloth in a day. Our balloon program was to call for millions of yards of high-count cloth, and this meant the construction of thousands of new looms as well as the training of hundreds of weavers.

Naturally our cotton manufacturers were reluctant to undertake such a production, and their fears were justified when we found that the earliest deliveries of balloon cloth were frequently as high as 67 per cent imperfect. By the middle of 1918, however, the mills had so perfected their methods that the wastage amounted to only 10 per cent of the cloth woven. This wastage was largely caused by "slubs," knots, and other imperfections which prevented an even surface for rubberizing. Because of the lives which depended upon having perfect balloon cloth, the fabric was inspected literally inch by inch, and hundreds of men and women had to be specially educated in this inspection work.

The development of the new art of weaving balloon cloth was an achievement of no mean degree. In April, 1917, all our cotton mills put together could produce only enough cloth to build two balloons a week. In November, 1918, our looms were turning out cloth sufficient for ten balloons a day, an expansion in the industry amounting to 3,000 per cent in nineteen months. This expansion proceeded at a rate that always kept us a little ahead of the military schedule. To produce ten balloons a day the cotton mills had to turn out 600,000 yards of special cloth a month. In addition to the small army of weavers, this production called into service 3,200 looms. Had the war continued another year, we should have reached our goal of fifteen complete new kite balloons produced every day. Our complete project of balloons and dirigibles of all types called for a total output of 20,000,000 yards of balloon cloth. Had we reached the quantity production planned, we should have been able to supply not only our own needs, but also all

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those of the Allies in Europe. America had the raw material necessary for the whole anti-German balloon program.

As it was, we supplied to France and England a considerable number of balloons when the shortage of materials in those countries was becoming acute. The foreign users of this American-made equipment reported that it was equal to the best European product. It should have been. No war material was ever manufactured more conscientiously than this. In addition to the painstaking care of the producers, from start to finish a large force of inspectors watched every step in the construction of each balloon, and when America sent a balloon to the front it was right for the work it had to perform.

The weaving of the cloth was but the first step in the production of the balloon fabric. The fabric of the balloon envelope resembles a sandwich in its construction, there being a thin film of specially compounded rubber between two plies of the cotton cloth. The outer ply of the cloth is cut on the bias. This method prevents any long, straight tear down the grain of the fabric. The threads of the inner ply are set at an angle of 45 degrees to those of the outer ply, thus distributing strain sufficiently to stop a "snag" practically where it starts.

The cotton cloth alone can not resist the seepage of gas, and therefore it is necessary to rubberize it, the rubber film being really the gas-resisting envelope. In the rubberizing process the cloth must be run through the spreading machine from thirty to thirty-five times in order to build up the thin rubber film without a flaw in it of any kind. The outside ply of the balloon fabric is "spread," that is, painted, with a rubber compound containing a coloring matter. This compound makes the fabric waterproof; it gives also protective coloring to the balloon when in the air, making it less visible to the enemy; and, finally and most important, this coloring absorbs the actinic rays of the sun, which are fatal to the life of rubber. In some of the fabric the rubber film itself was colored to withstand both the heat and the ultra-violet rays,

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thus both protecting the rubber and reflecting the heat, which would otherwise expand the gas in the balloon.

Though in general we adopted the European standards of construction, we had to develop our own rubber compounds and cures as well as our various fabrication processes. The latest reports we received from the front stated that not only was the American fabric successful, but that it had an added characteristic which was a direct means of saving life. It was discovered that the American fabric, by burning more slowly than the European balloon fabric, gave the men in the observation basket more time to get away in the parachutes when the balloons were destroyed by hostile attack.

When we went into the war we had never built a windlass for a kite balloon. The ability of the American manufacturer solved this problem as it did almost every other problem in the development of war instruments. Steam was the motive power first used for windlasses, but before the fighting came to an end America had developed both gas and electric windlasses which were thoroughly efficient.

The best-known type of gasoline windlass was that with two motors, one to turn the cable drum controlling the balloon's ascent and descent, and one to move the windlass itself along the road. A record pull-down speed of 1,600 feet a minute, or more than three times the speed of the fastest passenger elevator, was attained by the gasoline windlass.

The electric windlass pulled down the balloon at the slower rate of 1,200 feet a minute, but it was smoother in operation. The mobile windlass would move on a road under its own power at twenty miles an hour and could tow the balloon in the air at the rate of five miles an hour, or even faster if necessity demanded.

To play on the safe side at the start, we adopted a satisfactory windlass that had been developed in France. It was difficult to manufacture this entirely French machine with American materials and methods; yet James Cunningham, Sons & Company, of Rochester, New York, succeeded in attaining a delivery of four complete windlasses a week.

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Photo from B. F. Goodrich Company

CUTTING AND CEMENTING BALLOON CLOTH PANELS

Photo from B. F. Goodrich Company

ASSEMBLING BALLOONS

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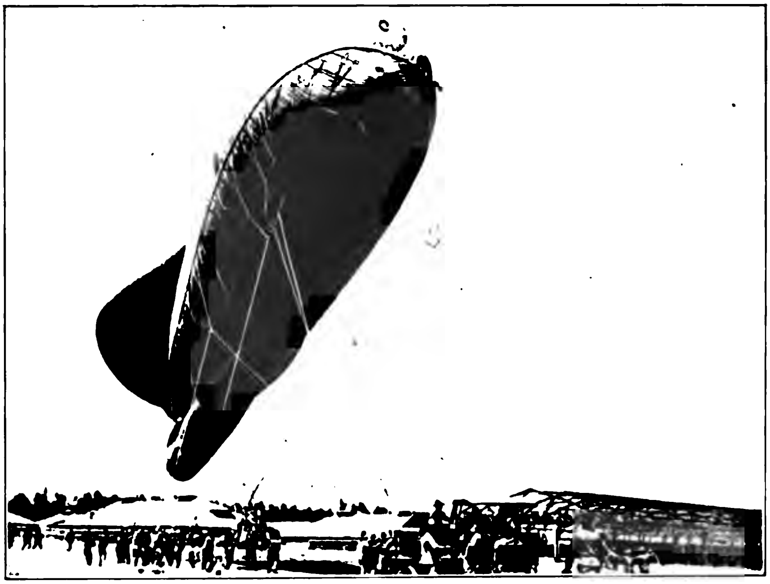

Photo from Air Service

AMERICAN CAQUOT BALLOON ASCENDING

Photo by Signal Corps

AMERICAN WINDLASS FOR OBSERVATION BALLOON

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In addition to this windlass we designed two of our own. One was the product of the United States Army Balloon School and was manufactured by the McKeen Motor Car Company, of Omaha, Nebraska; the other was designed and manufactured by the N. C. L. Engineering Company, of Providence, Rhode Island. Both were put into quantity production, assuring us of a sufficient number of the best windlasses ever manufactured.

The first cable used to hold the balloon captive was approximately a quarter-inch in diameter, weighed one pound for each eight feet of length, had a breaking strength of 6,900 pounds, and was made of seven twisted strands of plow-steel wire, containing in all 133 separate wires. This cable, though it accomplished the original purpose, was early seen to have fine possibilities of development. The observers in the basket must be kept in constant communication with the artillery and their own windlass, and this communication could best and most efficiently be obtained by means of the telephone. The balloon telephone, as first used, was an entirely individual unit with its own separate cable from the basket to the ground. In this way communication was indeed established, but only at the cost of a decrease in possible altitude, increased cable resistance, and the necessity of an extra windlass for winding and unwinding the telephone cable. Previously to the entrance of the United States into the war, preliminary experiments in France were being made with a view to putting the telephone wires in the center of the main cable, thus doing away entirely with the second cable and windlass; but there had never been developed a satisfactory cable of this construction. American inventiveness at the John A. Roebling Sons Company and the American Steel & Wire Company plants was set to work on this problem, with the result that not only was a satisfactory cable developed, but a steady production was attained, 50,000 feet a week being delivered regularly by the John A. Roebling Sons Company alone. This new cable consisted of 114 separate wires of special steel, besides the telephone center of three copper wires prop-

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erly insulated and armored. The specifications demanded a breaking strength of 7,200 pounds; the actual test of the finished Roebling cable showed 8,250 pounds.

Another of the balloon problems was the supply of hydrogen gas. Before the war only a little hydrogen was used in this country, the element being a by-product in the manufacture of commercial oxygen. We met the additional demand for millions of cubic feet of hydrogen for our balloons by establishing government gas plants and expanding privately owned plants already in existence. There were two methods of supplying hydrogen to our balloon units at home and abroad. One of these was by furnishing portable plants which would generate hydrogen at the place where it was to be used. The other was to take the hydrogen from the stationary plants, condense it by pressure in steel cylinders, and ship it to points of demand. By far the greater part of the gas which we used, not only in this country, but also in France, was produced at the permanent supply stations and shipped in cylinders. Each cylinder held about 191 cubic feet of gas under a pressure of 2,000 pounds to the square inch at 68 degrees Fahrenheit. When the war ended we had placed orders for 172,800 of these cylinders, of which 89,225 had been delivered and were in use. We developed a manifold filler which would take the gas of from twelve to twenty-four cylinders at the same time and quickly inflate a kite balloon, a speed of twenty-three minutes for a complete inflation having been reported from one training camp.

In the production of portable hydrogen generators we had to produce not only the machine, but also the chemicals required in the process. We adopted the ferrosilicon-and-caustic-soda process, by which it was possible to produce 10,000 cubic feet of hydrogen an hour in a field generator. There was plenty of caustic soda to be had, but high-grade ferrosilicon, a production of large electrolytic furnaces, was scarce, because of its heavy consumption in the steel industry. We procured, however, 2,482 tons of it for our generators, of which over 2,360

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tons were supplied by the Electro-Metallurgical Sales Corporation alone.

An interesting feature of the gas supply in the field was the use of "nurse balloons." The nurse balloon was simply a large rubberized fabric bag with a capacity of 5,000 cubic feet of gas. It was used for storage of gas, and the observation balloons were fed from it. The consumption of hydrogen by the war balloons was heavy. To cite one item, private manufacturers, previously to the signing of the armistice, produced and delivered 17,634,353 cubic feet of hydrogen and were in a position to meet practically any demand for the gas. This figure is only a small part of the total, for it does not include the hydrogen produced in the permanent government stations or by the field generators.

Hydrogen, though the lightest of cheap gases, and therefore the one universally used in balloons, has the grave fault of being dangerous to the balloonist. When mixed with air it is highly explosive if touched off by a spark of fire or electricity. For years balloonists have dreamed of a gas, light enough to have great lifting power, which would not burn or explode. There was such a gas known to chemistry—helium, discovered first in spectroscope examinations of the corona of the sun, but later found by chemists to exist rather freely in the atmospheric envelope of the earth. Although one of every 100 parts of air is pure helium, it was not until comparatively recent years that this light nonexplosive gas was discovered in our atmosphere. Now, helium was rare and expensive, and until the United States entered the war no one had considered its production as a commercial possibility. Up to two years ago the total world production of helium since its discovery had not been more than 100 cubic feet in all, and the gas cost about $1,700 a cubic foot.

It had been discovered that certain natural gases issuing from the ground in the United States contained limited quantities of helium. The question was whether we could extract this helium in sufficient quantities to make its use practicable. The Signal Corps, the Navy, and the Bureau of Mines com-

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bined in a coöperative plan to develop a practical helium production. By adopting a method of obtaining the helium from liquefied gas produced in the processes of the Linde Air Products Company and the Air Reduction Company, and also by the Norton process, we attained astonishing success in this enterprise. On the day the armistice was signed we had at the docks, ready for loading on board ships, 147,000 cubic feet of helium. At its prewar value this gas would have been worth about $250,000,000. On November 11, 1918, we were building plants which would produce helium at the rate of 50,000 cubic feet a day, and the cost of obtaining it had dropped from $1,700 a cubic foot to approximately ten cents.

None of this gas was actually used in the war, but its production by our chemists was hailed as the greatest step ever taken in the development of ballooning. It now seems to have opened a new era in lighter-than-air navigation. In war helium will nullify the incendiary bullet which destroyed so many balloons and airships. In peace it brings the possibilities of new types of construction of dirigible airships, for its use eliminates entirely all the dangers from lightning, static electricity, and sparks and flames from gasoline engines or any other source.

The Army and Navy coöperated in the production of balloons. The Army furnished the balloon cloth to the Navy. Navy balloons had two automatic safety valves for the expanding gas, one on each side of the balloon a third of the way back from the nose and just above the equator; the Army held to the French and British idea of a single valve in the nose itself. The Navy adopted a Caquot-type balloon which rode at an angle of about 25 degrees to the horizontal and was somewhat smaller than the army model. The Navy used these balloons as spotters for submarines and mines. They were towed on cables from the decks of warships, and were connected with the ships by telephone.

The use of parachutes with balloons is a comparatively recent development, the man who first successfully descended to earth in a parachute in fact, having been during the war, the

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chief inspector of all United States army balloons and parachutes. This was Major Thomas S. Baldwin, known the world over as Captain Tom Baldwin, hero of innumerable aërial exploits of all kinds, under all conditions, and in all parts of the world. The Yankee balloon observer in France went up to his observation post in the security of knowing that the equipment on which his life depended had been O. K.'d by men who knew the business from beginning to end.

The parachute as it is known at the county fair and the parachute used in the recent war were far apart in type. The war parachute embodied all the improvements that the world's aëronautical experts could add to it. The need for parachutes developed when hostile aviators began shooting down the sausages. At first the one-man parachute was used exclusively, the men in the basket leaping overboard the instant their balloon was fired over their heads. Any delay on their part would be fatal, since the entire bag would be consumed in fifteen or twenty seconds and the observer would then be unable to leap out of the falling basket. When the individual parachutes were used, the maps and records in the balloon basket were usually lost. To overcome these difficulties, the designers invented the basket parachute. This was considerably larger than the individual parachute. To operate it the balloonists pulled a cord which cut the basket away from the balloon entirely. The spreading parachute overhead then floated the basket, with the men themselves and all else it contained, safely and quickly to the ground.

Although hundreds and even thousands of parachute jumps occurred during the war, there were few fatalities from this cause. During all the time our forces were at the front, only one of our men was killed as the direct result of a parachute drop. In that particular instance the burning balloon fell on top of the open parachute, setting it on fire and allowing the observer to fall unprotected the rest of the distance to the ground. One of our observers was known to make four jumps from his balloon on the same busy day, and another leaped thrice in four hours. In the Argonne offensive thirty parachute

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jumps were made by our men. As for the safety of our parachute equipment, the only complaint from the Yankee balloonists at the front was that it was too safe. The man who is escaping from a German airplane, nose-diving at him with a machine gun spitting fire, is in a hurry; he does not wish to be detained by a parachute which floats him too leisurely to the earth.

In the rigging of each kite balloon there were about 2,000 feet of rope of different sorts. There was a deficit of proper cordage in the United States at first, and the French thought they could furnish this rigging to us. But their attempt proved to be unsuccessful, and we were forced to develop a cordage manufacture in this country of high quality and great quantity. We did this so swiftly that there was no serious delay to the balloon production.

Up to November 11, 1918, we produced over 1,000 balloons of all kinds, 642 of these being of the final Caquot type which we adopted. This production included many propaganda balloons for carrying printed matter over the lines into the enemy's country. We supplied several target balloons for gun practice on our aviation fields. We developed new types of parachutes and built acres of canvas hangars for balloons. We produced 1,221,582 feet of steel mooring cable. These are only the major items in the balloon enterprise; hundreds of others of less importance are excluded.

The balloon production was one of the most important and successful of all our war projects. Although we had a limited knowledge of the subject in the beginning, our balloons stood the hard test of actual service and could bear comparison in every way with the best balloons of Europe, where the art of balloon building had been in existence for many years. Once our production actually started, we never had any shortage of balloons for our own Army; and soon we should have been in a position to produce the observation balloons for all the armies fighting Germany, if called upon to do so.

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— own element. At no time did the anti-German

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CHAPTER XXIII

WARSHIPS AND FLYING BOATS

THE declaration of war on April 6, 1917, found the American Navy just setting out upon the most ambitious shipbuilding program it had ever known. In the preceding August Congress had adopted the so-called three-year naval building program, authorizing the expenditure of the then unprecedented sum of $500,000,000 for more than 150 new naval vessels. Before the end of 1916 the Navy had let contracts and the builders were beginning the work of constructing four battleships, four battle cruisers (a new type for our Navy), four scout cruisers, twenty destroyers, twenty-seven submarines, and several auxiliary and supply ships. In size, power, and cost of the vessels involved, this construction program was far beyond anything the Government had ever before attempted. It was adopted because the United States was existing within a circle of armed belligerents, and no man could foresee what the future might bring forth. Therefore the program as laid down was a general one; it was a program meant to give us a balanced fleet—one which could defend the United States against any foe.

The declaration of war changed the conditions by giving us now a specific enemy—Germany. Against Germany new capital ships were of little use to us, for the combined fleets of the Allies, plus the great additional power which the American Navy could add with its existing commissioned fleet, was amply sufficient to hold the German surface fleet in its bases. What was needed was craft with which to fight the German submarines: small, light-draft, swift, easily maneuvered surface vessels, as well as submarines for meeting the enemy in his own element. At no time did the anti-German

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forces at sea feel that they had enough such vessels. Therefore, as soon as the United States became a belligerent the Bureau of Construction and Repair, which is the Navy's builder of ships, suspended the construction of the battleships, battle cruisers, and other large ships, in order to devote all facilities and energy to the construction of existing types, and the development and construction of new types, of anti-submarine vessels.

Of these the destroyer was the most important. It was the convoying ship used in the war zones. The records later showed that the destroyers accounted for more German submarines than did the surface craft of any other one class. America was well advanced in the development of the destroyer. No naval constructor on earth had contributed more to the destroyer than had Admiral D. W. Taylor, Chief Constructor, U. S. N., and Chief of the Bureau of Construction and Repair. He it was who gave the American destroyers of the classes before 1915 their distinctive high freeboard forward, and he had added other features of design leading to greater effectiveness. Admiral Taylor was known to naval men as "the father of the destroyer."

The Navy came into the war with Germany with fifty modern destroyers and thirty-three smaller ones of earlier date. These latter had become obsolete, but they were placed again in service during 1917 and served throughout the war. The modern expansion of our destroyer fleet began in 1906, and by the spring of 1917 it had delivered fifty-eight destroyers to the Navy. Fifty of these were ready for service when war was declared. About half of them were of the 700-ton type. In 1911 we began building 1,000-ton destroyers. In 1915 the American designers carried the high freeboard of the bow throughout the length of the vessel, thereby producing what was known as the flush-deck type. The destroyer of this type was of 1,100 tons displacement and 310 feet long. This vessel, a 30-knot boat, was the most advanced destroyer in use by our Navy on the date of the declaration of war.

Meanwhile, however, a further advance in the design of the

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destroyer had been made by the Navy. The three-year program had authorized the construction of fifty destroyers, twenty of them the first year, as noted above. In the design of these, further improvements were added, the chief one being in speed, which was raised to thirty-five knots an hour. The 1916 boats, like those of 1915, were 310 feet long, but their displacement was nearly 1,200 tons. With some slight changes, this was the design for all the destroyers laid down in the war program adopted later.

The expedition shown by the Navy in the autumn of 1916 in placing its destroyer contracts bore its own reward, for many of the boats undertaken then were finished in time to be of service in the war zone.

War construction proper of destroyers began before the declaration of war against Germany. On March 4, 1917, the President approved an act of Congress authorizing the immediate construction of fifteen of the fifty destroyers provided for in the three-year program (these in addition to the twenty already under construction). The act also carried an emergency fund of $115,000,000 which the President might spend for still additional destroyers, the usefulness of which in combating the submarine had been demonstrated to the world by the British Navy. The contracts for the fifteen were all placed before April 6; and under the provisions of the emergency fund the Bureau of Construction and Repair proceeded to place orders for seventy-six more. All these contracts were in force before the middle of August, 1917, at which time the Navy therefore had 111 destroyers under construction. These, added to the fifty in commission and the thirty-three obsolete destroyers and torpedo boats, would give the Navy nearly two hundred destroyers and destroyer-type vessels with which to fight submarines.

But even this great project, far beyond anything our naval constructors had ever known before, was not regarded by them as anything more than a fair beginning for the war construction program. It was impossible to build too many destroyers so long as the submarine seriously menaced the United States.

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On October 6, 1917, Congress granted another money appropriation for destroyers,—$350,000,000 this time,—on the strength of which the Navy placed orders for 150 additional destroyers. In 1918 twelve more were ordered from various navy yards; so that the total of war orders for destroyers, including the twenty ordered in the autumn of 1916, was 273. Thirty-eight were delivered and commissioned before the armistice. After the armistice it was found to be possible to cancel economically the contracts for the construction of only six of the destroyers which were being built on war orders. The total war construction of destroyers, therefore, both before and after the armistice, produced 267 of these useful vessels.

The war builders of destroyers were the Bath Iron Works, the Fore River Shipbuilding Company (Quincy, Massachusetts), the Union Iron Works (San Francisco), William Cramp & Sons (Philadelphia), Newport News Shipbuilding Company, New York Shipbuilding Company, Bethlehem Shipbuilding Corporation, Mare Island Navy Yard, Charlestown Navy Yard, and the Norfolk Navy Yard.

In the prosecution of the destroyer construction program during the war, two phenomena are to be noted as exceptional: (1) the increase in the rate of construction at the shipyards, and (2) the building of the great plant at Squantum, Massachusetts, near Boston, for the construction of destroyers.

Before 1914 the average time for building a destroyer for the Government was about two years and a half, counting from the day Congress authorized the construction until the builders delivered the boat ready for commissioning. This was not only the American average, but the average in other countries as well. After the war started and Germany began to use her submarines against merchant shipping, the naval builders of Europe speeded up their processes, but even then it took two years to build a destroyer. The American builders in the war succeeded in cutting this time in two on the average; and in exceptional instances the time of construction was reduced far below this average. The Mare Island Navy Yard laid the keel of the destroyer *Ward* on May 15, 1918, and

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launched the hull on June 1—seventeen and one-half days! Machinery and fittings had been installed and the vessel was delivered to the Navy for its trials on the first day of September—109 days after the laying of the keel! The Squantum plant delivered the destroyer *Mahan* for the trials 174 days after the keel was laid. These were the extreme records for speed in construction, but the hundreds of other destroyer projects did not lag far behind these marks. On the average it took less than a year to turn out a destroyer during the war.

There were not enough shipbuilding facilities in the United States to turn out destroyers in the numbers desired by the Navy, which therefore undertook to provide new facilities. There was a large expansion of the plant of the Union Iron Works at San Francisco, but the most notable development was at Squantum. Here the Fore River Shipbuilding Company (which had been acquired by the Bethlehem Shipbuilding Corporation), acting as agent for the Government, filled and graded a large tract of swampy ground and roofed over forty-three acres of it—practically with a single roof. Even the building ways and the slips in which the floating hulls were fitted out were covered. The ground was broken for this operation in October, 1917, and on November 30, 1918, the first completed vessel was delivered. Its keel had been laid on April 20. This plant built the hulls only and afterwards fitted them out, but the boilers and machinery were constructed elsewhere.

CHASERS AND EAGLE BOATS

As soon as it became evident that the United States was to be drawn into the war, the Bureau of Construction and Repair began making an inventory of privately owned yachts and other pleasure boats which might be used in the war zone as anti-submarine craft. The investigation showed a surprisingly small number of these boats fit for such service. The principal objection to them, from the Navy's standpoint, was their unseaworthiness. For the most part they were fair-weather boats. The Navy, therefore, in coöperation with a number of yacht builders, undertook to design a 110-foot, 75-ton power

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boat which would be seaworthy and adapted to rapid construction. It was to be driven by gasoline engines and, in order not to conflict with the merchant and naval shipbuilding programs, to be built of wood. The result of the design and the subsequent construction was the American submarine chaser, a conspicuous part of our naval forces at sea during the war days.

All this development was a prewar activity. In fact, almost the complete submarine-chaser program was inaugurated before the actual declaration of war. On March 19, 1917, the New York Navy Yard was ordered to build sixty of these boats, and the New Orleans Naval Station four. Two days later, contracts were placed with private firms for forty-one chasers, and the contracts placed before April 1 called for the delivery of 355 boats. Later on ninety-two more were ordered (fifty of these for the French Government, which received fifty of the first boats and was thoroughly convinced of their usefulness), so that the total war orders were for 447 boats, of which all but six were subsequently delivered to the Navy.

The submarine chasers were known by the designation *S. C.*, followed by the numerals by which the individual boats were identified. They could cruise at nearly seventeen knots an hour and could be worked up to eighteen knots when the occasion demanded. Each carried depth charges and a Y-gun projector, two machine guns, and one of the 3-inch, 23-caliber boat guns specially designed by the Navy for this service.* The crew of the submarine chaser consisted of two officers and twenty-four enlisted men. The New York Navy Yard completed and delivered its first boat in fifty days, and subsequent construction was even more rapid. In appearance these vessels, with their white flush decks, their miniature bridges, and their mahogany and brass fittings, were such as to make a sportsman's eyes glitter. The submarine chasers proved to be surprisingly seaworthy. One flotilla of them came unscathed through a gale that badly battered the larger naval vessels

* See page 305.

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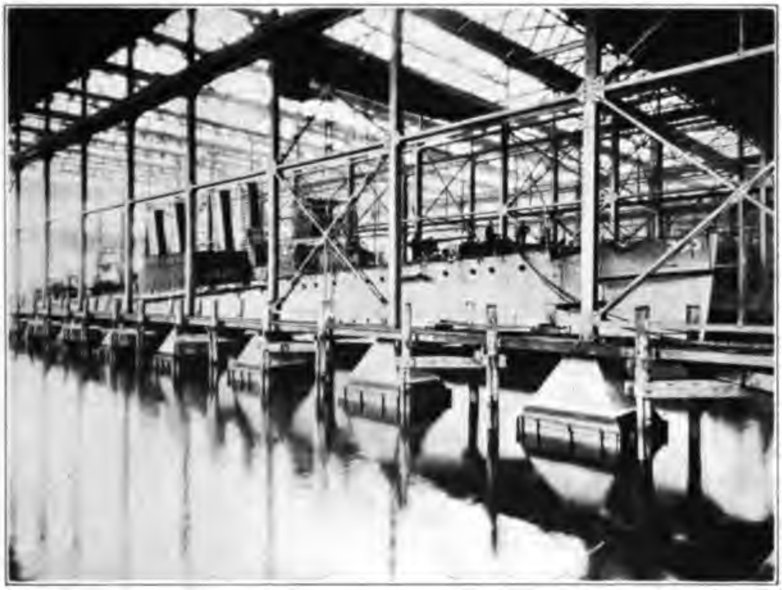

Photo from Bureau of Construction and Repair, U. S. N.

BUILDING DESTROYER IN COVERED SLIP AT SQUANTUM

Photo from Ford Motor Company

BUILDING AN EAGLE BOAT

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Photo from Bureau of Construction and Repair, U. S. N.

A SUBMARINE CHASER

Photo from Ford Motor Company

EAGLE BOATS ON RIVER ROUGE, DETROIT

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escorting them. They were also highly effective in the work for which they were built—hunting submarines.

The submarine chasers were built by the two navy yards mentioned and by a large number of yacht and small-boat builders on the Atlantic and Gulf coasts and on the Great Lakes.

Before the submarine chasers had time to demonstrate their usefulness the Navy turned to the development of new types of anti-submarine boats that might be built to supplement the destroyers. All the facilities in the country were loaded with destroyer contracts, but the Navy felt that facilities might be found for the construction of smaller craft which could do the work of destroyers in the war zone. About this time, too (autumn of 1917), progress was being made in the development of listening equipment, with which it was hoped that surface vessels would be able to detect and locate submerged submarines accurately. The listening gear developed never came up to expectations in effectiveness, but nevertheless the Navy prepared for its use. The destroyers were too noisy to serve as effective listening vessels, unless they stopped their machinery altogether. Consequently the Bureau of Construction and Repair began experimenting with the design of a steel vessel smaller than the modern destroyers, but considerably larger than the submarine chaser then under construction; a vessel which should have considerable speed and cruising radius, and which should be in every way a genuine ship of war.

Coincidentally, while the Navy was working out these plans Mr. Henry Ford, of Detroit, communicated with the Department (on December 24, 1917) suggesting that the Ford Motor Company build for the American Navy a new type of war vessel which he called a "submarine detector-destroyer." He proposed a vessel virtually as powerful as a destroyer in operations against submarines, but smaller and of simpler design, and capable, by the use of the quantity-production methods of the Ford Motor Company, of being built in a much shorter time. The Secretary of the Navy immediately

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telegraphed to Mr. Ford to bring a force of his engineers and production experts to Washington to consult with the Navy's own designers. The result was a series of conferences in which the basic principles of design were adopted. On January 12 the navy designers had worked out complete plans and specifications. Three days later Mr. Ford named the price at which the boats could be built—$275,000 for each ship as a maximum—and the Navy thereupon ordered the Ford Motor Company to build 100 such vessels. Thus was inaugurated the famous project to build Eagle boats (as they were promptly named by the Secretary of the Navy) on the bank of the Detroit River.

The public generally did not realize what an extensive project this was. The popular impression was that the Ford Company was building some sort of power boat or submarine chaser for the Government, but few understood that this vessel was actually larger than any destroyer built in the United States before 1903. The Eagle boat was 200 feet long and 25 wide, and it had a displacement of 500 tons. It was driven by a steam turbine engine developing 2,000 horsepower. Its normal speed was over eighteen knots an hour. It could cruise 3,500 miles with the oil which could be loaded into its tanks. It carried a crew of five officers and sixty-eight men, and its armament consisted of two 4-inch guns, two machine guns, one 3-inch anti-aircraft gun, and a Y-gun for depth bombs.

The boat was peculiar in appearance, for, in order to facilitate rapid building by forces inexperienced in ship construction, it was constructed of flat plates along straight lines. Nevertheless it proved to be seaworthy, keeping dry decks in fairly bad weather, although it rolled heavily in a sea coming in off the boat's quarter. Being equipped with a single turbine (an engine which is not flexible in starting, stopping, and reversing), the vessel was hard to handle around docks; but it was managed easily when under way. In 1919 some of the Eagle boats were used between ports of North Russia, and they

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successfully cut through ice fields without damage to themselves.

In his original communication Mr. Ford had estimated that he could build such boats six times faster than destroyers could be built and at one-sixth the cost. The cost estimate was fairly accurate, but the motor-car builder erred widely in his time estimate. In the original contract the company undertook to build its plant and deliver the first Eagle boat in five months or less, to deliver ten boats within the next month, and to reach a standard quantity production of twenty-five boats a month after November 1, 1918. The new plant, however, experienced great difficulty in making the boats water-tight and oil-tight, and also found it harder to finish them than had been expected. Consequently only three boats were finished before the armistice. Four others, nearly complete, were caught in the ice when the attempt was made to take them to salt water for finishing, and the following spring they were towed back to the Ford plant to be fitted there for service.

The Ford Company built in all sixty Eagle boats for the Navy, delivering the last one on November 12, 1919. In September of that year the company finished twenty-three of them, thus nearly equaling the projected rate of production.

In order to conduct this enterprise, the Ford Motor Company built a special shipbuilding plant at River Rouge, Detroit. The main building was 1,702 feet long and 306 feet wide. This plant, put up in about 100 days, was ready for operation on May 1, 1918. The first keel was laid by May 7. The principal innovation adopted by the company in its shipbuilding was its method of launching. From time immemorial vessels of such size had been built on land and launched into the water down greased ways. The Ford Company built its boats on trucks which ran along an erecting track. When one stage of manufacture was complete, the trucks, carrying the unfinished boat, were rolled to the next station for the next operation, and so on until the hull reached the end of the shop, a finished boat ready for the water. The trucks were then run

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upon a large hydraulic table, floating in the slip. The table was submerged, and the Eagle boat floated clear.

SUBMARINES

The Bureau of Construction and Repair designed two types of mine sweepers early in 1917, and during the war contracted for the construction of fifty-four of them. Seventeen of these were delivered before the armistice. The Bureau converted the merchant vessels into mine-laying ships for the fleet referred to in Chapter XVI. The Bureau also converted and repaired all vessels taken over by the Navy during the war and mounted the guns for the arming of 370 merchant ships. After January, 1918, the Bureau was in exclusive charge of the camouflaging of American naval and merchant vessels. With practically all shipping under government control, the Bureau early in 1918 commandeered the equipment of the three principal vessel salvage companies operating on the Atlantic coast, and thereafter conducted all marine salvaging operations until the end of the war.

As it developed, the submarine itself proved to be an effective vessel for fighting the submarine. Throughout the summer and early fall of 1917 numerous isolated merchant vessels had been sunk by enemy submarines in the vicinity of the Azores. In October the Navy sent a division of American submarines to the Azores, and after that the sinkings of merchant shipping in that vicinity became appreciably fewer. The presence of our own under-water vessels in that region had the effect of driving the enemy's away.

The importance of the submarine in anti-submarine operations was not thoroughly appreciated by our Navy at first, and submarine construction received a relatively low rating in the priority schedules. In the summer of 1917 the Navy received from the Allies information which led the Bureau of Construction and Repair to place the construction of submarines just after that of destroyers in priority rating. This decision came too late to result in any extraordinary production of submersibles during the war. However, the three-year program had

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authorized the construction of fifty-eight submarines, the contracts for the construction of thirty of which were immediately placed. The appropriation act of March 4, 1917, authorized the construction of eighteen more of those provided for in the three-year program, and also specifically authorized the construction of twenty additional submarines. In August, 1918, under the authority of war legislation, the Bureau placed contracts for twenty-four additional submarines, making a total of ninety-two under-water boats contracted for after August 29, 1916. Forty American submarines were completed and commissioned before the armistice. These included six boats of old design which had been partially completed in American yards for the defunct Russian Government.

It should be stated that the machinery for the operation of all these new war vessels was provided by the Navy Department's Bureau of Steam Engineering. The problems met and solved by this Bureau in finding the necessary manufacturing facilities were often as great as similar ones in any other branch of the war munitions enterprise.

PARAVANES

It fell to the Bureau of Construction and Repair to build the paravanes, the individual mine-sweeping apparatus with which most of our naval and merchant ships were equipped during the war. The paravane was an impenetrable secret until the armistice. In our Navy Department it was forbidden to speak or write the word "paravane." The device was always referred to as the "PV" or the "Otter gear." It was probably the most successful of the new devices developed by naval inventors during the war.

The apparatus enabled any vessel equipped with it to sweep a safe path for itself through a mine field. The principle of the paravane was essentially that of the water kite. In appearance a paravane was like a torpedo. It carried a large plane, slightly curved like the wing of an airplane, which slipped vertically through the water. These torpedo-like objects were towed from the bow of the vessel, one on each side. The action of the

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plane caused the paravane to stand away from the ship almost vertically. By means of fins or rudders, the paravane could also be made to tow at any desired depth. A ship equipped with paravanes, traveling at full speed, would be flanked on both sides by submerged water kites, each straining away from the ship and each nearly as far forward as the vessel's bow. The pull of the paravane on its towing rope was so considerable that a special wire rope had to be used. The two towing ropes were attached to the forefoot of the vessel—*i.e.*, under water at the forward end of the keel. When the ship was in motion the two towing ropes acted as a strong wedge, the forefoot of the vessel forming its apex. Whenever one of these towing ropes engaged a cable which moored a mine, it deflected the mine and its mooring away from the ship and out to the paravane. At the point where the towing rope was attached to the paravane there was a so-called cutter-head, with jaws of steel knives. The cutter-head could easily sever any mine-mooring cable; and the released mine, being buoyant, would quickly rise to the surface, where it could be seen, avoided, and destroyed.

The paravane was the invention of Commander C. D. Hurney of the Royal Navy. In May, 1917, the Bureau of Construction and Repair received plans and drawings of the paravane from the British Government. Three types of the gear, for vessels of various speeds, were put in manufacture at the plant of the W. E. Bliss Company, of Brooklyn, the principal torpedo manufacturers in this country. The John A. Roebling Sons Company manufactured the towing rope. The Bliss Company turned out in all approximately 2,000 paravanes, and in addition the Navy bought about 650 others from Vickers, Limited, in England.

It was necessary to instruct the officers of the Navy in the value and use of the paravane. For that purpose the steamer *Berkshire*, of the Merchants' & Miners' Line, was taken over and turned into an instruction ship, with a lecture room and motion-picture machine. The *Berkshire* made over 100 runs in this service, operating from City Island in New York harbor.

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On these runs she cut specially laid mines with her paravanes, which were afterwards hauled on board to allow the passengers to inspect them.

On September 7, 1918, the starboard paravane of the battleship *South Carolina* cut a German mine laid six miles off the New Jersey coast. The British records at the time of the armistice showed authentic instances of seventy-two mines cut adrift by paravanes, which fact probably means that equally as many vessels were saved from destruction by the device.

The British made an extensive use of poison gas in the battle of Jutland. The coincidence that the crews of the major German ships in that action had been equipped with gas masks only two days before the battle saved thousands of German sailors from death. As it was, they were able to operate their ships even when the holds were filled with deadly fumes. When America entered the war it was evident, then, that gas warfare was just as much a fact at sea as on land; and the Navy, therefore, through the Bureau of Construction and Repair, proceeded to meet the condition by providing itself with gas masks. The Navy designed its own masks, procuring 75,000 in the spring of 1917 and 95,000 of an improved design in 1918. The navy masks were markedly different from those used by the Army. The soldiers carried the canisters, which contained the chemicals for absorbing and neutralizing lethal gases, in knapsacks suspended from their shoulders. The navy mask was self-contained—that is, the canister was part of the headpiece.

SEAPLANES

Besides building vessels for the Navy, the Bureau of Construction and Repair also built the Navy's aircraft used in the war. The Navy's aircraft problem, like that of the Army, consisted of the two branches—training planes and service planes. All of the Navy's planes, however, both for training and for service, had to be built with pontoons, so that they would float, for they must be able to land on and take off from the water. There were peculiar elements that differen-

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tiated the Navy's aircraft problem from that of the Army. In the first place the Navy was unaware at the outset whether it would send any aircraft abroad at all. In September, 1917, it was decided that the Navy should establish and operate fifteen seaplane stations on the coasts of France and Ireland, a decision which initiated the program of building service seaplanes. In the second place, practically all the advanced development in airplane design had been with land planes. None of the Allies had developed a thoroughly satisfactory seaplane for coastal patrol duty. In this development, therefore, America started in on an even footing with all of them.

There was little difficulty about the construction of an adequate number of training planes, although the Navy had never found a satisfactory type before the autumn of 1916. The great navy bill of 1916, however, provided $1,000,000 for naval aëronautics. Meanwhile the Navy had been using planes of the pusher type. So many fatal accidents had happened with these that flying at the Navy's training station at Pensacola had ceased. With the million dollars in hand, the Bureau called Mr. G. H. Curtiss to Washington and proposed a new design, which should be the Curtiss JN plane, a tractor then being produced for the Army, equipped with a pontoon and with added wing and tail areas for greater lifting power and increased stability. The Army used the Curtiss JN plane for its training in 1917-1918, and practically the only complaint about it was that it was too safe, if anything; so safe as to leave the student unprepared for the swifter and less stable pursuit planes which he would have to manage later on. As thus modified, it proved to be in every respect a satisfactory machine for the training of naval aviators. The navy plane was known as the N-9.

In the autumn of 1916 the Navy ordered thirty of these machines from the Curtiss Aeroplane & Motor Corporation of Buffalo. When the United States declared war against Germany large classes of navy aviators were in training with these machines. After the declaration of war the Navy ordered sixty-four additional N-9's and seventy-six seaplanes of a similar,

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but larger, type known as the R-6. These contracts loaded the Curtiss Corporation to the capacity of its space allotted to the Navy by the Joint Army and Navy Aircraft Board; but the Navy needed more training planes. It therefore turned to the Burgess Company, of Marblehead, Massachusetts, the Boeing Airplane Company of Seattle, and the Aeromarine Plane & Motor Company of Keyport, New Jersey. These concerns, which had been assigned exclusively to the Navy, accepted large orders for training planes, either Curtiss N-9's or similar machines of their own designing—Burgess, Boeing, and Willard seaplanes. These orders called for 292 seaplanes, in addition to the 140 ordered from Curtiss. In addition the Curtiss Corporation at its Buffalo plant accepted orders for 137 more training planes. These early orders were followed by others later on. All the deliveries of training seaplanes were satisfactory—so satisfactory that in the early fall of 1918 it was found necessary to reduce the orders for training planes because the Navy was getting too many of them.

In producing service seaplanes the Bureau of Construction and Repair concentrated on only two types, both of Curtiss design, one, known as the HS-2, being a single-engine machine, and the other, a larger one, called the H-16, having twin engines. By concentrating upon these the Navy was able to secure heavy production. The Liberty engine was the chief factor in the success of the Navy in producing service seaplanes. Seaplanes are heavier than land planes, and the main obstacle in the way of an earlier development of them in Europe had been the lack of aëro engines of sufficient power to lift and drive them. Soon after we entered the war America had, in the Liberty engine, the most powerful airplane engine then in existence and one of the lightest for its power. Having this, the Navy was able to develop seaplanes on an equality with any of the Allies.

The genesis of the HS-2 single-engine seaplane was as follows: In the summer of 1917 the Curtiss Corporation brought out a seaplane (called the H-14) which was driven by two 100-horsepower engines. This machine was a failure, because

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its power was insufficient. The Curtiss Corporation experimented with a single 200-horsepower engine, which was still not sufficient for the plane. When the Liberty engine was receiving its first bench tests, the Navy arranged with the Curtiss Corporation to install a Liberty in an HS boat. This was done, and the plane was successfully flown over Lake Erie on October 21, 1917. Incidentally, this was the first time a Liberty engine was put into the air, the Navy having won its friendly contest with the Army over which should be first to test the new mechanism in flight.

It was seen at once that the HS boat, equipped with the Liberty engine, would be a valuable service plane for the Navy, and the Bureau of Construction and Repair immediately bought from the Curtiss Corporation unlimited rights to produce this machine—an action taken in order to enable other manufacturers to build the seaplane. After some preliminary changes had been ordered during the earlier manufacturing stages, the HS-2 machine, as it was then called, had a wing span of seventy-four feet; it could lift 6,500 pounds, its useful load including two pilots, two 230-pound bombs, a machine gun, and a radio outfit; and it had a maximum speed of eighty-five miles an hour and an endurance of six and one-half hours at cruising speed. From six producers 1,236 HS-2 boats were ordered, and 1,091 were built and delivered before the armistice, of which 229 were sent to the American seaplane stations abroad. The builders of the HS boats were the Curtiss Corporation, the L. W. F. Engineering Company of College Point, Long Island, the Standard Aircraft Company of Elizabeth, New Jersey, the Gallaudet Aircraft Corporation of East Greenwich, Rhode Island, the Boeing Airplane Company, and the Loughead Company of Los Angeles. Numerous yacht builders acted as subcontractors for the boat hulls.

In 1914 the Curtiss Corporation designed and built the airplane *America*, which had its day of fame as a heavier-than-air machine which would attempt the transatlantic flight. The *America* was unsuccessful for the reason, common enough in

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that early day, that there were no engines sufficiently powerful to drive heavy airplanes; but it did prove to be the progenitor of the largest service plane produced and used by the Navy during the war—the H-16.

After the war began in Europe there was a rapid development of airplane engines abroad; and in 1915 and 1916 the British, seeking a serviceable seaplane, took the original *America* model and fitted it with two 100-horsepower French Anzani engines. Thus powered, the plane flew successfully. The Admiralty ordered a number from the Curtiss Corporation and used them to patrol submarine areas. They were known as the Small Americas.

Presently the Rolls-Royce airplane engine, more powerful than its predecessors, was developed in England. To provide for the use of this engine, the Curtiss people brought out a larger model of the Small America, which the Admiralty in England fitted with twin Rolls-Royce engines. This machine the British called the Large America. The admiralty constructors redesigned the hull for greater strength, introducing the steep V bottom; and this machine was in production at the Curtiss plant when the Liberty engine was designed. At the factory the model was then called the H-16.

The Bureau of Construction and Repair decided to go into a heavy production of this model for the American naval forces abroad, equipping the boat with twin Liberty engines. This meant practically a redesign of the model, for it is no simple thing to change engines in a flying machine. Every airplane is built especially for the engine which is to drive it. Questions of balance and stability in planes are delicate ones, and when an engine is changed a complete rearrangement of the distribution of weight is usually necessary. Nevertheless, the Navy accomplished this change without undue difficulty, and placed orders for 296 H-16 planes. All of these were built and delivered before the armistice, and 158 of them went to the naval coastal air stations abroad. The builders were the Curtiss Aeroplane & Motor Corporation, the Curtiss Engineer-

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ing Corporation, and the Naval Aircraft Factory at Philadelphia, of which something is to be said later.

The H–16, with its great power and its ninety-five feet of wing span, could carry a load of 3,500 pounds and make as high as ninety-five miles an hour; but the British did not rest content with it. In 1918 the admiralty constructors completely redesigned the machine to give it far greater wing spread, increasing its allowable load to 13,000 pounds. The redesigned machine, known as the F–5, could carry four depth bombs (as compared with two carried by the H–16) and could cruise for eleven hours at a stretch, against nine hours' cruising endurance for the H–16. The speed of the F–5, however, was slightly less.

The Bureau of Construction and Repair redesigned this model to take Liberty engines and to be adaptable to quantity production by the assembly method. It ordered 410 of them from the Curtiss Aeroplane & Motor Corporation and 50 additional ones from Canadian Aeroplanes (Ltd.), of Toronto, and then placed an order for 680 such machines with the new Naval Aircraft Factory in Philadelphia. The pre-armistice deliveries of the American F–5 totaled 227 machines, of which 137 came from the Naval Aircraft Factory. Thus the total production of twin-engine service seaplanes for the Navy during the war—H–16's and F–5's—amounted to 520 machines. Only one F–5 boat was shipped to Europe. The total production of all service planes for the Navy, including the HS–2 single-engine boats, was 1,611, of which 388 went to the naval stations abroad.

In order to secure such production the Bureau of Construction and Repair was forced to undertake a large expansion of the facilities for airplane manufacture. When from our naval forces in Europe came large requisitions for the twin-engine boats, the factories at the disposal of the Navy were already loaded almost to capacity with orders for training planes and single-engine service planes. Somewhere or other the Navy had to find facilities for the production of 480 planes over and above what the existing plants could turn out.

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It was realized that the Government would have to finance this operation, and, as a second consideration, the limits of time were such that it was impracticable to attempt the establishment of a self-contained plant: *i.e.*, one that should both manufacture the parts and assemble them. Accordingly it was decided to enlist various yacht builders and metal-working and woodworking shops as builders of hulls, wing panels, and other parts, and to create a great government plant which should receive the parts and assemble them into finished machines. On February 9, 1918, the Secretary of the Navy authorized an extension to the existing aircraft factory at the Philadelphia Navy Yard. This factory had been built in 110 days during the late summer and fall of 1917, and was already an extensive institution, the chief feature of which was a main factory building 400 feet square. The plant was a complete unit, making parts and assembling them; and in February, when the extension was authorized, it was engaged in a project to build fifty H–16 flying boats, the first of which flew successfully in its trials on March 27, 1918. The extension after February 9 added a great assembly building, panel shop, varnishing room, storehouses, power plant, and the like; so that the enlarged plant covered forty acres and cost nearly $3,700,000. At the time of the armistice it employed over 3,600 persons, one-fourth of whom were women trained in the work at the special school conducted by the plant.

The Navy's airplane program reached quantity production about September 1, 1918, when the factories were turning out an average of eighty-three machines a week. Of these, thirty-two were training planes, thirty-eight single-engine service planes, and thirteen twin-engine service planes. Nearly twenty yacht builders and metal-working establishments were turning out hulls, wings, and other parts of this construction. Among the auxiliary concerns should be mentioned the Victor Talking Machine Company of Camden, New Jersey, which devoted its plant almost exclusively to the production of parts for assembly by the Naval Aircraft Factory.

The Navy shared with the Army the difficulties of procur-

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ing spruce, wing fabric, dope, and other raw materials used in airplane manufacture. For its fabric and dope the Navy depended upon the Army, and was at all times satisfactorily served with these materials. The Navy, however, conducted an independent operation in securing spruce. When, in December, 1917, the Army started its development of the airplane spruce industry in the Pacific Northwest, there was no assurance as to the date when spruce in satisfactory quantities would begin to come from the northwestern mills. The Navy decided not to rely upon this source. Before the war the airplane builders had used New England spruce, and Germany had purchased this spruce for her airplane builders. Yet when we entered the war this source of the wood seemed to have been overlooked. In the early winter of 1917-1918 the Navy sent an officer into the New England woods, and he reported in January, 1918, that the Navy could secure the lumber there at the rate of 1,000,000 feet a month, and at prices considerably under what was being paid for Sitka spruce. The Navy decided to develop this source. It established an office in Boston, and during the spring of 1918 the New England mills turned out airplane spruce at the rate predicted.

New England spruce is not clear timber like Sitka spruce, but is full of pin knots; and the manufacturers hesitated to use it on that score. Practical experience, however, showed that the wood was not weakened by these knots; that it was, if anything, a strut stock superior to Sitka spruce. The production from the New England mills was greater than the Navy could use, and during the development the Department sold several million feet of it to the British and to the American army contractors. The prices paid by the Government for New England spruce were $125, $110, and $100 a thousand feet for the first three grades, as compared with $642, $350, and $160 a thousand for the same grades of Sitka spruce.

THE NC BOATS

While the Navy was producing its service planes of the adopted designs, it was simultaneously encouraging the pro-

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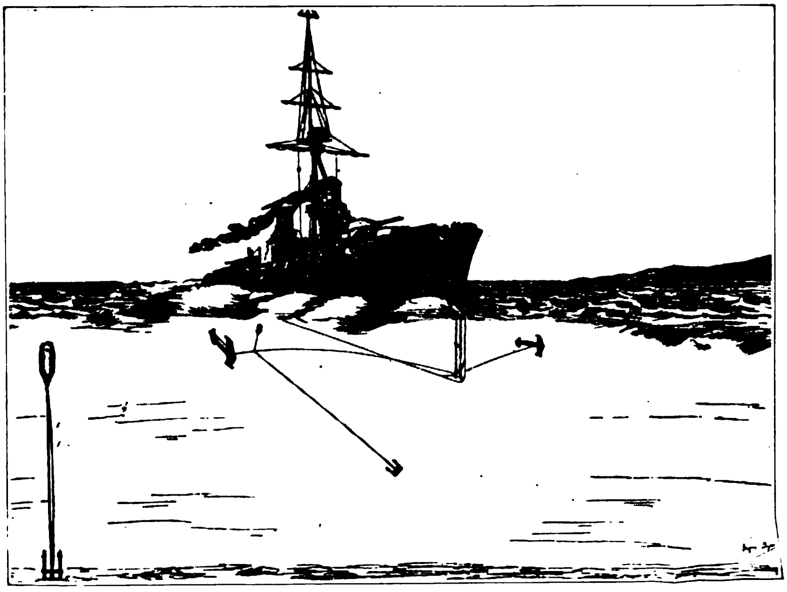
Photo from Bureau of Construction and Repair, U. S. N.

AN HS-2 SEAPLANE



Drawing from Bureau of Construction and Repair, U. S. N.

PARAVANES IN OPERATION

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NAVY DIRIGIBLE OF B CLASS

Photo from Bureau of Construction and Repair, U. S. N.

THE *NC-4* AT FAYAL, AZORES

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ducers to develop new, advanced designs of airplanes. Several notable models came from this experimentation, and some of them were adopted; but this development came too late to place any of the machines in service during the war.

The Curtiss Engineering Corporation developed a land fighting machine for the protection of coastal bombing squadrons. This was a triplane which, equipped with a Curtiss K–12 engine, made 162 miles an hour in a test flight, a world's record for speed at that time. The machine was known as the 18–T, or Kirkham fighter. The same concern also developed a single-pontoon seaplane, known as the HA, which, with a single Liberty engine, made 125 miles an hour—remarkable speed for a flying boat. The Gallaudet Aircraft Corporation brought out a promising pusher-type seaplane, with the Liberty engine, however, mounted forward, the power being transmitted to the propeller by a ring gear. Both the Aeromarine Plane & Motor Company and the Curtiss Engineering Corporation brought out improved training boats which were adopted by the Navy.

These novelties, however, brought forth no such public acclaim as did the NC boats, one of which became the first heavier-than-air machine to cross the Atlantic Ocean in flight. The NC flying boat was the joint design of the Navy and the Curtiss Engineering Corporation,—hence its designating initials,—called forth in response to the war demand for seaplanes of greater cruising radii and weight-carrying ability. The project was undertaken in the late summer of 1917, when the largest flying boat in existence was an early model of the H–16 equipped with twin Rolls-Royce engines. This ship had a cruising radius of 500 miles. The Navy was looking for a plane that could carry a heavy load of depth bombs across the ocean if necessary—one that could proceed to the hunting ground at daybreak, stay aloft all day, and return to its base at dark. For this purpose the naval designers consulted with Mr. Glenn H. Curtiss, who, within a few days, submitted preliminary designs for two biplanes, both essentially alike in principle, but one to be equipped with five engines developing

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1,700 horsepower, and the other with three developing 1,000 horsepower. These were far larger than any seaplanes in existence. The chief innovations were the designs of hull and tail. The hull was much shorter in proportion than those in use, and the tail, instead of being supported entirely by the hull, was to be supported partially by the hull and partially by outriggers from the upper wing beams.

The Navy decided to adopt the smaller machine, the one with three engines. In working out the design for this machine with the engineering force of the Curtiss Corporation, the Navy, for the first time in the history of airplane construction, used the strictly scientific method. All airplanes of new model in that day and time were built by the empiric method. The builder roughly sketched his design, built a plane accordingly, and then, if the machine failed to perform as it was expected to, made changes in the construction, and kept on making changes until the model was either a success or definitely a failure. The NC project was far too great and too costly for the Navy to trust to any such slipshod plan. The design for the plane was worked out scientifically with as much care as would be put into the design of a bridge or a battleship. All pressures, weights, stresses, resistances, and so on, were exactly calculated in advance, so that the designers were able to tell with practically complete accuracy what a machine built according to the design would do in actual flight. In fact, the original calculations showed that a boat, weighing under 25,000 pounds, as projected, and driven by the power specified, taking into consideration the other factors to be worked into the design, would not have the speed at first estimated, and therefore would not have a radius of flight that could carry it from Newfoundland to Ireland. Thus, before a dollar was spent for materials, the Navy definitely abandoned a transatlantic seaplane as impracticable at that time, and took up the design of a plane of slightly smaller weight (22,000 pounds) which should have a flight radius sufficient to take it from America to the Azores.

And this was the seaplane finally constructed. On its test

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flights it left the water weighing, with its load, 22,000 pounds as projected, but was able to fly at a slower speed than the design had indicated. Its maximum speed, eighty miles an hour, was greater than that calculated in the design. The Navy tried the experiment of installing a fourth Liberty engine in the plane, and with this added power it flew successfully when weighing, with its load, 28,000 pounds. Four engines were thereupon definitely adopted for the plane. The NC boat that crossed the ocean, like the others, carried two Liberty engines, one tractor and one pusher in tandem in the center nacelle, and one tractor engine in a nacelle on each side of the center.

The design for the NC boats was completed in January, 1918. The Curtiss Engineering Corporation assembled the ships and built the hull of one of the four ordered. The Navy itself, Locke & Company, of New York, Unger Brothers, of Newark, the Beaver Machine Works, of Newark, Brewster & Company, of New York, the Albany Boat Corporation, Watervliet, New York, the Pigeon Fraser Hollow Spar Company, of East Boston, Massachusetts, the Aluminum Company of America, of Pittsburgh, Pennsylvania, Lawley & Sons, of Neponset, Massachusetts, and the Herreshoff Manufacturing Company, Bristol, Rhode Island, supplied parts. The NC–1 was tested on October 4, 1918.

DIRIGIBLES

Up to the time of the declaration of war the Navy had never built a successful dirigible balloon. The A–1, which was contracted for in 1917, was delivered to the Navy in April, 1917, but it was not a success; it was not good enough to be used even for training purposes. Dirigible construction was a rigidly guarded military secret in Europe. The French and the Germans had been the most successful builders of dirigibles, but naturally they kept their knowledge to themselves. The English, during the early years of the war, developed a small airship for sea patrol, but we knew little about its performances in use. In December, 1916, the Bureau of Construction and Repair, U. S. N., began working on the design of a ship

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that should have a cruising endurance of twelve hours, a speed of forty-five miles an hour, and lifting capacity sufficient to carry a crew of three men with their equipment. Early in the year 1917 such a design was completed—one providing for a dirigible 160 feet long, with a 100-horsepower engine, maximum speed of forty-five miles an hour, and an endurance of sixteen hours at thirty-five miles an hour.

When, in February, 1917, the United States broke off relations with Germany, the Secretary of the Navy at once ordered the Bureau to proceed with the construction of sixteen such airships. Ordinarily, before going ahead with the procurement of a new model the Bureau of Construction and Repair would build and try out a test ship, but under the conditions of early 1917 there was no time for such action. The only concern in the United States which had even attempted to build dirigible balloons was the Connecticut Aircraft Company, and its attempt had not been successful. The Goodyear Rubber Company at Akron, however, had built a few free balloons. The contracts for the sixteen dirigibles of the B class, as the new design was called, were placed with the Goodyear and Connecticut Aircraft companies, and with the Curtiss Aeroplane & Motor Corporation, the Goodrich Rubber Company, and the United States Rubber Company. The last-named company did not build complete ships, but supplied fabric to the Connecticut Aircraft Company. Of the sixteen ships, Goodyear undertook to build nine.

The Goodyear Company established a dirigible testing field at Akron, with airship shed, hydrogen generating plant, and barracks. This field was ready on June 1, 1917, but before that date the company had completed the first dirigible of the B class. The Goodrich Company had acquired a suitable hangar at Chicago, and there the Goodyear ship was sent for its test. On the second test trip the dirigible behaved so satisfactorily that the two Goodyear test pilots aboard decided to head for Akron. The ship left Chicago at midnight and landed in a field ten miles from Akron at noon the next day, after one of the longest distance flights on record up to that time.

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The trials of the B–1 proved the type to be serviceable. All sixteen of the ships were manufactured and delivered before the summer of 1918.

During the early months of 1918 there was some doubt as to the advisability of using dirigibles in the European war zone, because of the weather conditions; but with the advent of spring and good weather our foreign observers again became convinced of their effectiveness. The result was that the Bureau proceeded with the design of a larger and faster ship. The fruits of this effort were the American dirigibles of the C class—each 192 feet long, having a lift of 12,700 pounds, the extraordinary maximum speed of 60 miles an hour, and an endurance of 47 hours in air at 45 miles an hour, or 2,150 miles. Ships of the C design were made of fabric coated with bright aluminum powder to stop the actinic rays of the sun, which deteriorate balloon fabric rapidly. During 1918 contracts for the construction of thirty such airships were placed with the Goodyear and Goodrich companies. After the armistice half of these orders were canceled.

The C–1 was completed and tested in September, 1918, and proved to be a successful ship, at least the equal of any dirigible of its size built at that time. The C–5, completed after the armistice, in May, 1919, flew from Montauk to Newfoundland, expecting to proceed from there on a transatlantic flight to Ireland. The ship, however, had to be moored in an open field, and it was blown out to sea by a gale and lost.

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CHAPTER XXIV

TOXIC GASES

THE first recorded use of suffocating gases in warfare occurred about 431 B. C., sulphur fumes having been employed in besieging the cities of Platæa and Belium in the war between the Athenians and the Spartans. Similar uses of toxic substances are recorded during the Middle Ages. In August, 1855, the English Admiral Lord Dundonald, having observed the deadly effect of the fumes of sulphur in Sicily, proposed to reduce Sebastopol by sulphur fumes, and worked out the details of the proposition. The English Government disapproved the proposition on the ground that "the effects were so horrible that no honorable combatant could use the means required to produce them."

That the probable use of poison gases was still in the minds of military men is evidenced by the fact that at The Hague Conference in 1899 several of the more prominent nations of Europe and Asia pledged themselves not to use any projectiles whose only object was to give out suffocating or poisonous gases. Many of the Powers did not sign this declaration until later. Germany signed and ratified it on September 4, 1900, but the United States never signed it. Further, this declaration was not to be binding in any war in which a nonsignatory should become a belligerent. Admiral Mahan, a United States delegate, stated his position in regard to the use of gas in shell, at that time an untried theory, as follows:

> The reproach of cruelty and perfidy addressed against these supposed shells was equally uttered previously against firearms and torpedoes, although both are now employed without scruple. It is illogical and not demonstrably humane to be tender about asphyxiating men with gas, when all are prepared to admit that it is allowable to blow the bottom

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out of an ironclad at midnight, throwing four or five hundred men into the sea to be choked by the water, with scarcely the remotest chance to escape.

The Second Hague Peace Congress in 1907 adopted rules for land warfare, and among them was Article XXIII, which read as follows: "It is expressly forbidden to employ poisons or poisonous weapons."

In spite of these international prohibitions, there seems to be little question that, before the World War broke out in 1914, Germany planned the use of noxious chemicals in warfare and devoted research to that end. It is a widespread belief that the first use of gas in the war occurred on April 22, 1915, when the Germans made an attack with chlorine, a common and well-known gas, against the unprotected Canadians and French in the northeastern part of the upper Ypres salient. The use of chlorine as a free, drifting gas, or even the employment of the gas projectors used by the Germans at Ypres, would not prove that the Germans had contemplated this method of attack before the outbreak of the war in 1914, since chlorine was easily obtained, and the projectors could have been manufactured in a short time. But evidence is coming to light that Germany, several months before the Ypres attack, used gas against the Russians on the eastern front, and used this gas in shell. Gas shell did not appear on the western front until a considerable interval had elapsed after the Ypres incident.

Now, it is impossible to produce gas shell within a few weeks after the inception of the idea of using them. The pioneers in the manufacture of artillery shell filled with poisons must have had to experiment before they found a satisfactory method of filling the shell; and after that the metal shell themselves had to be manufactured, a process requiring at least several months. Yet there is testimony that the Germans fired gas shell at the Russians in the Masurian district in December, 1914, within five months after the outbreak of the war. The plain indication is that Germany not only planned the use of chemicals in the event of a great war,

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but probably had actually manufactured the gas shell while the rest of the world fancied itself in the security of permanent peace.

The evidence that the Germans used gas shell against the Russians long before the chlorine fog enveloped the Canadians at Ypres comes in the memoirs of two generals of the war, Ludendorff, the German, and Gourko, the Russian. In *My War Memories*, on page 121, Ludendorff, speaking of the German preparations for the attack upon the Russians that occurred on January 31, 1915, wrote: "For this purpose our General Headquarters placed eighteen thousand rounds of gas shells at our disposal." On the next page, describing the attack itself, he said: "The weather was too cold for a gas attack, although that as yet we did not realize."

This is inferential and not direct testimony that the Germans were using gas shell on the eastern front that winter, but for confirmation of the fact that such shell were employed by them, we may turn to General Gourko's *Russia in 1914-1917*. "About the end of December [1914]," wrote Gourko, "the Germans introduced a method of fighting which up to this time had never been used in warfare between civilized nations—shells charged with asphyxiating gases." General Gourko describes the attack in which the gas shell were fired and the counter-attack that retook the trenches for the Russians. The Russian trenches were found to be filled with the apparently lifeless bodies of both Russian and German soldiers, and these old trenches were filled in to be a general grave. Later some of those yet unburied were found to be still alive, but in a deep stupor from which they did not emerge for hours. Then it was discovered that gas shell had been fired by the Germans in the battle and that some of the German troops had fallen victims of their own gas in the occupied Russian trenches. Gourko hints that some of those buried might have been still alive. Later on in his book he refers again to this gas attack of December, 1914.

Gas, though extremely effective as a weapon and dreadful in its immediate effects, actually came to be one of the most

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humane weapons of warfare. The American troops in France suffered more than 72,000 gas casualties, the gas cases being about 33 per cent of the total number of wounded. Twelve hundred of these gas casualties died, or less than 2 per cent of the total number gassed. The death rate from battle wounds of other sorts was much higher. As a general rule the gas victims made complete recoveries in time. The most serious after-effects proved to be a few cases of chronic bronchitis and a few permanent contractions of the larynx and trachea. A few victims later suffered from irritable hearts. The surgical records of the Army, however, give no basis for the popular belief that gassed men are more susceptible than others to tuberculosis.

Since Germany had chosen to utilize toxic gas in warfare, the Allied nations were compelled to adopt like tactics. Accordingly England and France, faced with the desperate situation resulting from advantages secured by the Germans through the employment of these new weapons, immediately turned their attention not only to devising methods for protecting their own troops, but also to securing the supplies and equipment necessary for the utilization of toxic gas as an agent of warfare against the German Army. Germany originated thereafter the use of most of the new forms of gas, but the Allied nations and America were actually producing, at the time of the armistice, gases on a much greater scale than Germany was ever able to attain. In fact, America herself was producing gases at a rate several times as great as was possible in Germany.

Before the entry of America into the war, our overseas observers had been collecting information bearing upon gas warfare and referring the facts so obtained to the Ordnance Department in Washington, where the information was turned over to Lieutenant Colonel E. J. W. Ragsdale, who was then in charge of the Trench Warfare Section. In the early days of our belligerency it was seen that we should need a plant for filling artillery shell with toxic gases. In the fall of 1917 the Government bought a large tract of land near Aberdeen, Maryland, to be an artillery proving ground. Approximately 3,400

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acres of this reservation, about one-tenth of its area, was set aside as the site for the gas shell-filling plant. This reservation was known as Edgewood, and the plant erected on the site was called the Edgewood Arsenal. Work started on the construction of the arsenal on November 1, 1917.

None of the toxic gases in use in Europe, except chlorine and small amounts of phosgene, had ever been commercially prepared in the United States. It was the original intention to interest existing chemical firms in the manufacture of these gases; but there were many difficulties in the way of such a project, not the least of which was the ruling of the Director General of Railways that such products as poison gas must be transported only on special trains. Also, we discovered that the private chemical companies were loath to undertake such manufacture. The exhaustive investigations necessary before quantity methods of manufacture could be devised would be uncertain and expensive. There would be great danger to the lives of those employed in such work. Many of the private concerns were already crowded with war work. Finally, the new plant equipment which must be set up would be worth nothing when the war ended, since the manufacture of such gases would probably be limited to the period of hostilities. These and other considerations explain the reluctance of the commercial chemical industry to undertake the production of war gases.

Consequently the Government was forced to adopt the plan of building various chemical plants at the Edgewood Arsenal in connection with the filling plant. By December 1, 1917, it had been decided to build at Edgewood a chlorpicrin plant and a phosgene plant. The contracts were immediately let, and the work was pushed through the rigorous winter of 1917-1918.

In March, 1918, the Edgewood project was taken from the Trench Warfare Section of the Ordnance Department and made an independent division under the command of Colonel William H. Walker. In June, 1918, the Chemical Warfare Service was organized, and the Edgewood Arsenal was trans-

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ferred to it. General W. L. Sibert, Director of the Gas Service, took charge of the activities of the arsenal in May, prior to the official transfer.

Chlorine, the raw material for the manufacture of which is common salt, was one of the principal materials required in the gas-production program. Although chlorine was a standard product in the United States before the war, it was soon seen that our commercial supply was inadequate to meet the requirements of our proposed gas offensive. Chlorine was not only used by itself, but it was also the active agent in the manufacture of nearly all the other toxic gases which we required. Consequently we decided to build a government chlorine plant with two 50-ton units, giving a daily capacity of a hundred tons of liquid chlorine. The ground for this plant at Edgewood was broken on May 11, 1918, and the actual production of chlorine began on September 1.

In July, 1917, the Germans introduced the so-called mustard gas. It was immediately realized that, for certain purposes of fighting, this chemical was the most effective product so far employed, and a large number of government experts here at once concentrated their energies in developing methods for its manufacture on a large scale. Not only were the uniformed experimenters busy at the Gas Service's American University Camp, at Washington, D. C., but experimental units were established at the plant of the Dow Chemical Company, at Midland, Michigan, at the plant of Zinsser & Company, Hastings-on-Hudson, New York, and at the government plant which had been started by the Trench Warfare Section, at Cleveland, Ohio. Eventually it was decided to erect a large plant at Edgewood for the manufacture of mustard gas. Not until April, 1918, however, did we feel that we possessed sufficient knowledge and information to justify the construction of a mustard-gas plant on a large scale. France and England also were long in working out satisfactory methods of mustard-gas production. We began to make mustard in June, and continued with rapidly increasing output until the signing of the armistice.

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It soon became evident that, because of the danger involved, we could not depend upon civilian labor in the operation of the various chemical plants at Edgewood. It was decided, therefore, to utilize enlisted men in the working crews. As the projects at Edgewood increased in size and number, the forces at the arsenal grew, until at one time there were 7,400 troops at this point.

Meanwhile the Government had at last been able to persuade a number of private chemical firms to manufacture toxic gases. The Government agreed to finance all new construction, but the operation was to be in the hands of the contracting companies. At each plant the Government stationed one of its representatives, with the necessary assistants. In the spring of 1918, these scattered factories were made, by official order, part of the Edgewood Arsenal, each plant being designated by the name of the city or town where it was located. Thereafter in army usage the term "Edgewood Arsenal" embraced not only the group of factories on the Edgewood reservation, but also the following projects:

Niagara Falls plant, operated by the Oldbury Electro-Chemical Company. Project: the manufacture of phosgene.

Midland, Michigan, plant, operated by the Dow Chemical Company. Project: the sinking of seventeen brine wells for the purpose of securing adequate supplies of bromine.

Charleston, West Virginia, plant, operated by the Charleston Chemical Company. Project: the manufacture of sulphur chloride.

Bound Brook, New Jersey, plant, operated by Frank Hemingway (Inc.). Project: the manufacture of phosgene.

Buffalo plant, operated by the National Aniline & Chemical Company. Project: the manufacture of mustard gas.

In addition to these, the Edgewood Arsenal built, at points advantageous in supplies of raw materials, four other plants, and operated them as well. These were as follows:

Stamford, Connecticut, plant. Project: the manufacture of chlorpicrin.

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Photo from Chemical Warfare Service

CHLORPICRIN PLANT AT EDGEWOOD ARSENAL

Photo from Chemical Warfare Service

ONE OF EIGHT CELL ROOMS IN EDGEWOOD CHLORINE PLANT

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Photo from Chemical Warfare Service

FILLING 1-TON CONTAINERS WITH PHOSGENE

Photo from Chemical Warfare Service

FILLED GAS SHELL AND DRUMS STORED FOR LEAKAGE TEST

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Hastings-on-Hudson, New York, plant. Project: the manufacture of mustard gas.

Kingsport, Tennessee, plant. Project: the manufacture of brombenzyl cyanide.

Croyland, Pennsylvania, plant. Project: the manufacture of diphenylchlorarsine.

In constructing and equipping the Edgewood Arsenal we laid twenty-one miles of standard-gauge railway and fifteen miles of narrow-gauge railway, built nearly fifteen miles of improved roadway, and set up two water systems, one with a capacity of 1,500,000 gallons a day for the manufacturing purposes of the chemical plants, and the other, providing a fresh-water supply pumped four miles, with a daily capacity of 2,000,000 gallons. In all, 558 buildings were put up on the grounds of the arsenal. There were eighty-six cantonment buildings, with a capacity of 8,400 men, as well as adequate quarters for officers and civilian employees. Three field hospitals, a complete base hospital, and separate buildings for Y. M. C. A. and K. of C. activities indicated the extent of the building equipment. Three power houses were provided, with a total capacity of 26,500 kilowatts.

In the construction of buildings every precaution was taken to avoid accidents from the handling of toxic gas, the ventilating systems being as near perfection as human science could make them. It is notable that out of the thousands of men employed only four met their death by gas poisoning. Three of these casualties were due to phosgene and one to mustard gas.

As has been noted, chlorine was the only war gas produced on a commercial scale in America prior to the war. At the ordinary temperatures chlorine is a greenish yellow gas of strong, suffocating odor. Through the combined effects of cold and pressure it is readily condensed to a liquid and is ordinarily shipped in this form, stored in strong cylinders.

Chlorine is prepared commercially by the electrolytic process. A current of electricity is passed through a solution of common salt. The greenish gas at once arises, leaving behind it a

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Gas Casualties at Edgewood Arsenal, 1918

Toxic agent	*June*	*July*	*August*	*September*	*October*	*November*	*December*	*Total*
Mustard gas	14	41	190	153	227	47	2	674
Stannic chloride	...	3	8	15	21	3	...	50
Phosgene	...	...	3	7	22	17	1	50
Chlorpicrin	...	14	18	9	3	...	...	44
Bleach chlorine	...	2	39	2	1	...	...	44
Liquid chlorine	...	1	3	2	7	5	...	18
Sulphur chloride	...	...	2	1	6	...	...	9
Phosphorus	...	2	7	5	1	...	...	15
Caustic soda	...	...	3	...	3	4	...	10
Sulphuric acid	...	...	4	3	1	...	...	8
Picric acid	...	...	2	...	...	...	...	2
Carbon monoxide	...	...	...	...	1	...	...	1
Totals	14	63	279	197	293	76	3	925

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residue of caustic soda. The apparatus in which the salt is decomposed by the electric current is known as a cell. The government plant used Nelson cells, each with a capacity of sixty pounds of chlorine and sixty-five pounds of caustic soda every twenty-four hours.

The government chlorine plant at Edgewood was ready for operation in August, 1918, but was not actually started until September 1. The plant consisted of (1) a cell house, which had a total capacity of 100 tons of chlorine in twenty-four hours; (2) an electric substation for supplying the current; (3) a brine building, where the salt was mixed with water and the resulting brine purified; (4) a boiler and evaporation building, for concentrating the caustic soda from the cells; (5) a caustic fusion building, for drying the caustic soda and fusing it into solid form for shipment; and (6) a liquefying plant to condense and liquefy fifty tons of chlorine a day.

With the exception of chlorine, chlorpicrin was the first war gas to be manufactured on a large scale in this country. When pure, chlorpicrin is a colorless liquid which boils at a temperature of approximately 112 degrees C. The compound has been known since 1848. Though not so poisonous as some of the other products used in gas warfare, it is nevertheless an active poison, and has the additional advantage of being a fair lachrymator, or tear-producer. Chlorpicrin is made by the reaction between picric acid and chlorine. The chlorine is best supplied in the form of so-called bleaching powder, which is ordinary chloride of lime. In the manufacturing process as originally carried out, free picric acid was mixed with bleaching powder held in suspension with water. Later it was found advantageous to use calcium picrate instead of picric acid. Accordingly, the final process was as follows: The bleaching powder was creamed with water and mixed with a solution of calcium picrate in large stills holding 5,000 gallons or more. A jet of live steam was then introduced at the bottom of the still, and the reaction began at once, its rapidity depending upon the amount of steam introduced. The resulting chlorpicrin, together with a certain quantity of steam, passed out of

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the still and was liquefied in the condenser. The resulting mixture of chlorpicrin and water was run into tanks, where the chlorpicrin, being insoluble in water, gradually settled to the bottom and was run off and used directly in gas shell.

In developing this process the Government was assisted by the Dow Chemical Company, the Semet-Solvay Company, and the American Synthetic Color Company of Stamford, Connecticut, the principal work being done by representatives of the Bureau of Mines at the Stamford plant. America's whole supply of chlorpicrin during the war came from the American Synthetic Color Company and the Edgewood Arsenal. The Stamford plant was the first to reach large-scale production. The contract with the American Synthetic Color Company was dated December 13, 1917; and the company shipped over 111,853 pounds of the gas to Edgewood on March 11. This, when mixed with the necessary stannic chloride, supplies of which were already on the ground, was sufficient to fill approximately 100,000 75-millimeter shell. In the spring of 1918, because of certain internal troubles at the Stamford plant, it was agreed that the United States should lease this factory and operate it as a government plant. Under government operation, the total production of chlorpicrin at the Stamford plant amounted to 3,226,000 pounds, of which 2,703,300 pounds were shipped overseas in 660-pound drums. The chlorpicrin plant at Edgewood went into entire operation on June 14, 1918. Up to the signing of the armistice this plant had produced 2,320,000 pounds of chlorpicrin.

Phosgene was one of the deadliest gases employed in the war. Numerous other gases were used to annoy the enemy and force the wearing of masks, but phosgene was a killer, employed to produce as many casualties as possible. The gas did not persist long in the air or on the ground after the shell had exploded, so that it was an ideal chemical for use in an attack. The gas would clear away by the time the advancing troops reached the place of gas concentration.

Phosgene at ordinary temperatures is a colorless gas, but it condenses to a liquid at 8 degrees C. It is formed by the combi-

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nation of two gases, chlorine and carbon monoxide, in the presence of a catalyzer. The reaction is best conducted in iron boxes lined with lead and filled with charcoal of proper quality, into which boxes a stream of the reacting gases, mixed in proper proportions, is introduced. The reaction creates heat, and means must usually be taken to keep the reaction boxes cooled. The resulting phosgene is condensed to a liquid by passing it through a condenser which is surrounded by brine kept cold by refrigeration. The liquid is then stored in strong steel containers or run directly into Livens drums or artillery shell.

Before 1917, the Oldbury Electro-Chemical Company of Niagara Falls, New York, had set up a small experimental phosgene plant in the hope that the experiments might lead to the commercial utilization of carbon monoxide, which was obtained by this company as a by-product in the manufacture of phosphorus. When we entered the war the company had developed its process to such efficiency as to warrant the construction of a large phosgene plant, and the Government entered into a contract with the company for the creation of facilities with a capacity of ten tons of phosgene a day. Also, because of the great importance of phosgene in warfare, it was decided at the same time to build a government phosgene plant at Edgewood. A little later the Government financed a phosgene plant at the factory of Frank Hemingway (Inc.), at Bound Brook, New Jersey.

The total output of the original small experimental plant at Niagara Falls, which was later leased by the United States, was 83,070 pounds of phosgene, of which 24,800 pounds were shipped overseas. The contract with the Oldbury Chemical Company for its main phosgene plant was signed on January 15, 1918. Production here began on August 5 and by August 20 had reached a daily average of five tons. On November 1 the average daily production was seven tons. The total quantity produced at this plant was 435 tons. The plant loaded 18,768 Livens drums with phosgene, each drum holding about thirty pounds. This plant was operated by enlisted men.

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The contract with Frank Hemingway (Inc.) called for a factory producing five tons of phosgene daily by a secret process controlled by the company. The construction of the plant was begun on February 2, 1918, and phosgene was first manufactured on May 17. This concern reached its maximum of five tons a day by August 1, and produced in all 205 tons of phosgene.

Construction of the phosgene plant at Edgewood was begun on March 1, 1918. The plant consisted of four catalyzer buildings, each building having four units, and each unit possessing a projected capacity of five tons a day. The total capacity, therefore, was designed to be eighty tons a day. The carbon monoxide used in the process was produced by passing a mixture of oxygen and carbon dioxide over heated coke in a gas producer, the oxygen being supplied by a Claude machine with a capacity of 100,000 cubic feet of oxygen every twenty-four hours. The chlorine used came partly from the Edgewood chlorine plant and partly from outside sources.

The actual production of phosgene at Edgewood began on July 5, 1918, and worked up to an output of twenty tons a day by the date of the armistice. The total production of phosgene at Edgewood was 935 tons. The total output of phosgene from all three plants, Edgewood and the Bound Brook and Niagara Falls operations, at the date of the armistice was thirty-five tons a day; and this was increasing to reach ninety-five tons by March 1, 1919. The total phosgene produced by all the plants before the armistice was 1,616 tons.

The Germans, in spite of their attainments in chemistry, were never able to improve their clumsy and expensive methods of producing mustard gas. The best reports we have show that, at the time the fighting ended, all Germany's chemical warfare facilities could not produce more than six tons of mustard a day. The United States alone had ten times that capacity on the same date, and France and England both reached a heavy output. So concerned was the German high command because Germany was being outdistanced in the production of mustard gas that the ablest spy of the German

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Empire was sent into France in October, 1918, to find out the French method of making mustard. One of the chemical warfare officers who accompanied our forces into German territory reported that the Germans had decided to adopt the American method of making mustard gas and to stop their former process.

Mustard gas was by no means a child of the Great War, having been prepared in experimental quantities since 1886. It is a colorless, slightly oily liquid, boiling at 217 degrees C. with some decomposition. When perfectly pure it freezes at 13 degrees C.; but, since it usually contains small percentages of impurities, it usually remains liquid at 0 degrees C., or even below that. In chemistry the substance is known as dichlorethyl sulphide.

The first commercial process proposed for the manufacture of mustard gas depended upon the use of ethylene chlorhydrin; and on April 13, 1918, a contract was made with the Commercial Research Company, Flushing, Long Island, for the manufacture of ten tons a day by this process. In the spring and summer of 1918 a new process was developed both abroad and in the United States, one which used sulphur monochloride. Accordingly, the contract with the Commercial Research Company was canceled, and efforts were concentrated on the later process. This process consisted in blowing gaseous ethylene into liquid sulphur monochloride in large iron reaction vessels. The reaction develops much heat. Sulphur is set free by this reaction, and the temperature must be controlled in order to prevent the formation of solid sulphur in the reaction machine.

At the date of the armistice three mustard-gas plants were either completed or nearing completion. The construction of the Edgewood plant was begun on May 18, 1918, and the first mustard was produced exactly a month later. The changing of processes hampered production somewhat, but by September 20 the arsenal was producing ten tons a day, and by November 11 had increased this to thirty. The total production of mustard gas at Edgewood during the war period was

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711 tons, of which approximately 300 tons went into shell. On July 8, 1918, the Government began the construction of a mustard-gas plant at Hastings-on-Hudson, New York. This factory was to have a capacity of twenty-five tons a day, afterwards increased to fifty. The first unit of this plant was ready to operate when the armistice was signed. On July 6, 1918, the Government signed a contract with the National Aniline & Chemical Company, Buffalo, New York, calling for a mustard gas plant with a capacity of fifty tons daily. On November 11 this plant was 80 per cent complete. The cost of the plant was met by the Government, but the operation was to be in the hands of the Buffalo concern. The total daily capacity of all three plants, when complete, was estimated to be two hundred tons. To ensure an adequate supply of sulphur monochloride for its mustard-gas production the Government built a special plant at Edgewood with a daily capacity of three hundred tons of sulphur monochloride.

As soon as toxic-gas warfare had developed to a considerable extent, the perfection of gas-absorbing masks had given almost a complete protection against this new weapon, provided the soldier put on his gas mask in time. But the mask, especially the earlier forms of it, was not easy upon the wearer, because of the difficulty of breathing through it and also because it restricted the soldier's vision. It was soon discovered that a force compelled to wear its gas masks for any considerable period lost efficiency. The employment of gas by both sides for the purpose of forcing the opposite sides to wear masks continually was an important element in war at the close of hostilities. It was for this purpose that the so-called tear gases were produced. Gassing the enemy with tear gas was much cheaper than with poison gas, and it forced him to remain masked. The tear gases were highly effective. Even a trace of tear gas in the air would in a few moments blind a man temporarily. A single tear-gas shell could force the wearing of masks over an area so wide that it would require from 500 to 1,000 phosgene shell to produce the same effect.

Most of the tear gases had bromine bases. It was early de-

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termined that we should have to increase the American supply of bromine considerably if we were to meet our gas-warfare requirements. Bromine is a deep red liquid which boils at 63 degrees C. The domestic source of bromine is principally certain subterranean brines found in the United States, these solutions containing bromine in its compounds. The brines obtained in the vicinity of Midland, Michigan, are especially rich in bromine, and by far the largest amount of bromine obtained in this country comes from that locality.

In December, 1917, at a conference with Mr. Dow, of the Dow Chemical Company, Midland, Michigan, it was decided that the Government should finance the sinking of seventeen brine wells near Midland, the Dow Chemical Company to supervise the work and to produce the bromine from the brine. The work on this project was not begun until March, 1918, but the entire project was practically completed when the armistice was signed. This plant is a present war asset of the United States. It is capable of yielding approximately 650,000 pounds of bromine a year.

The tear gas which we prepared to manufacture was brombenzyl cyanide. It is a brownish, oily liquid which solidifies to white or brownish crystals at 29 degrees C. Its production involves a fairly intricate chemical process. The first step is to chlorinate ordinary toluol, one of the coal tar bases, to produce benzyl chloride. This chloride is then mixed with sodium cyanide in alcoholic solution and distilled, benzyl cyanide being the result. It is then only necessary to brominate the benzyl cyanide by treating it with bromine vapor.

The first manufacture of brombenzyl cyanide in the United States was conducted at an experimental plant at the American University Station at Washington. After this a large-scale plant was authorized at the plant of the Federal Dye & Chemical Company at Kingsport, Tennessee. The construction of this factory began on July 8, 1918, and operations started on October 29, the total production of brombenzyl cyanide being a trifle over five tons. In November the plant reached a capacity of three tons a day.

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The bromine gases were not poisonous in the sense of being killers, but were merely highly irritating to the membranes of the eye. The killing gases were phosgene, chlorpicrin, and chlorine. Mustard gas in sufficient amount was also fatal, its effect being identical with that of a deep burn. It attacked the lungs, the eyes, the skin, and even the intestines if food contaminated with it were swallowed. An insidious feature of mustard gas is the fact that its action is practically always delayed. A man might be gassed, even fatally, with mustard several hours before he became aware of it, and then it was too late to administer the treatment that might have saved his life. Goggles alone would have been sufficient protection against tear gas, but for the fact that it was invariably mixed with the deadlier gases.

The various experiments preliminary to our production of gases were conducted in provisional laboratories at the Bureau of Standards, Washington, D. C., Bureau of Mines, Washington, D. C., the Geophysical Laboratory, Washington, D. C., the Ohio State University, Columbus, Ohio, and Johns Hopkins University, Baltimore, Maryland. A control laboratory for the solution of problems arising in manufacture was eventually established at Edgewood. A total of 167,092 single chemical determinations was made at these laboratories under the direction of twenty commissioned officers, forty-five non-commissioned officers, and 204 privates.

The production of gases and other chemicals was only part of the work of the Edgewood Arsenal and its subsidiary plants. The other chief activity was filling artillery shell with the toxic substances. The description of the plant which filled shell with phosgene will indicate the scale upon which this operation was conducted.

The empty shell, after being inspected, were loaded on trucks, together with the proper number of loaded boosters. The booster was the device which exploded the shell and scattered the gas. Electric locomotives then pulled the shell trucks to the filling buildings. There were four of these to a single shell-filling plant, radiating at right angles from a common

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Photo from Chemical Warfare Service

FILLING 75-MILLIMETER SHELL WITH MUSTARD GAS

Photo from Chemical Warfare Service

FILLING LIVENS DRUMS WITH PHOSGENE

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Photo from Chemical Warfare Service

GAS CLOUD FROM BURSTING GAS SHELL

Photo from Chemical Warfare Service

PAINTING GAS SHELL TO DENOTE CONTENTS

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center. From the trucks the empty shell were lifted by hand to a belt conveyor which carried the shell slowly through a room kept cold by artificial refrigeration. Although the shell moved only seventy feet through this room, the conveyor traveled so slowly that they were thirty minutes in transit, and during this time they were cooled to a temperature of about 0 degrees F. This chilling was necessary because phosgene has a low boiling point, and it was necessary to keep the temperature of the metal of the shell considerably below the boiling point of phosgene in order that the gas might remain in liquid form while the filling was going on.

The chilled shell cases were next transferred to small trucks, each carrying six shell. The loaded truck was then drawn through a filling tunnel by means of a chain haul. This tunnel was so ingeniously contrived that the human assistance to the filling and closing machinery could all be conducted from the outside. The phosgene, kept liquid by refrigeration, was run into the shell by an automatic filler.

The truck was then moved forward a few feet to a point where the boosters were inserted into the noses of the shell by the hands of the operator, which reached in through an aperture in the tunnel. The final closing of the shell was then accomplished by motors. The air in the filling tunnel was constantly withdrawn by strong ventilation, the exhaust air being washed in stone towers by chemical agents to neutralize any gases that might be present. The filled, enclosed shell were next conveyed to a dump, where they were classified and then stood nose down for twenty-four hours to test them for leaks. Then they were painted, striped, and stenciled by air paintbrushes. The final process was to pack them in boxes and store them for shipment. This was done in large storage magazines on the grounds of the Edgewood Arsenal.

A similar method was used for filling shell with chlorpicrin, except that refrigeration was unnecessary. Mustard gas required another sort of filling machine.

Several filling plants were designed and constructed for

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filling grenades with stannic chloride and with white phosphorus, and also one for filling incendiary drop bombs.

The daily capacity of each of these plants was as follows:

Stannic chloride plant, hand grenades, 25,000. White phosphorus grenade plant, 30,000. White phosphorus smoke-shell plant, 155-millimeter shell, 2,000; or 4.7-inch or 5-inch shell, 4,000; or 75-millimeter shell, 6,000. Incendiary drop-bomb plant, 2,000.

The following sentences summarize the expected and actual production of the Edgewood Arsenal:

(1) The gas program as of March, 1918, called for approximately 545 tons of toxic gas weekly.

(2) The chemical warfare service program of August 12, 1918, called for a much larger amount, *viz.*, about 4,525 tons a week.

(3) The approximate filling capacity of the Edgewood Arsenal plant from August to November, 1918, was nearly 1,000 tons a week.

(4) The toxic-gas production during this same period increased from 450 to 675 tons a week.

(5) The capacity of all projectiles received, unlimited by boosters, varied during the same period from 125 to 450 tons a week.

(6) The maximum capacity corresponding to boosters received was less than 100 tons a week.

From these facts it will be seen that the numbers of empty shell delivered to the plant were far less than the numbers required to accommodate the gas production. Many of the shell received were without boosters and therefore without value until boosters were provided, so that the limiting factor was really the supply of boosters. The booster supply was sufficient to take care of only a relatively small fraction of the toxic gas actually produced. The filling capacity of the plant was also in excess of the delivery of shell and boosters. The 75-millimeter shell-filling plant had a capacity of 1,200,000 shell a month, and eventually of double that; whereas the

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delivery of shell was slightly over 300,000 a month and of boosters less than 200,000.

Because of the nature of toxic gas, it was thought to be impossible to store it in any large quantities. Early in the summer of 1918, large amounts were shipped in bulk overseas and there loaded into shell. Later we received instructions to stop all shipments in bulk except a limited amount of chlorine, and thereafter our production was limited to the number of shell and boosters available.

In June, 1918, we shipped in bulk fifteen tons of mustard gas, 705 tons of chlorpicrin, and forty-eight tons of phosgene. This was to be exchanged for gas shell produced by the French. In late July the French had no more extra shell to be filled with American gas, and this fact terminated the arrangement. However, we sold excess gas both to England and to France. England received 900 tons of our chlorpicrin and 368 tons of American phosgene. France took 300 tons of chlorpicrin and 1,408 tons of chlorine, which was equivalent to 1,226 tons of phosgene, since phosgene is 80 per cent chlorine, including allowance for wastage in manufacture. France furnished phosgene shell to us in exchange for chlorine. In addition, 200 tons of mustard gas were shipped to England and utilized by the English.

We therefore shipped to Europe in bulk 3,662 tons of gas or its equivalent, which gas was largely loaded in shell and used by the United States troops or those of the Allies. This quantity was sufficient to load 1,600,000 shell if two-thirds of them were of the 75-millimeter caliber and the other one-third 155-millimeter. This number is estimated to be at least equal to the total number of gas shell fired by American troops in action. Thus, although American gas was not actually fired in American shell against the Germans, American gas was used against the enemy, and America furnished at least as much gas as she fired.

In addition to this gas in bulk, we shipped 18,600 Livens drums loaded with phosgene. These contained 279 tons of gas, and some of them were fired at the enemy. We began pro-

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ducing loaded gas shell in the summer of 1918, and by August 9 had shipped 75,000 loaded 75-millimeter shell. These shell were unassembled for firing in the guns, the Ordnance Department having decided in June to assemble gas shell in their cartridge cases in France.

The chemical warfare production organization developed and manufactured a large number of special containers for the shipment of toxic gases. These were of special construction in order to guard against dangers from leaks, and all had to stand the tests required by the Bureau of Explosives before they would be received for railroad shipment. The 1-ton containers, each of which would hold one ton of liquid chlorine, were designed by the Ordnance Department. They would withstand a pressure of 500 pounds to the square inch. The 300-pound phosgene cylinders, designed by the Ordnance Department, were made to withstand a 500-pound hydrostatic pressure and a 250-pound air test. We purchased standard fifty-five gallon acid drums and standard-pattern cylinders for holding seventy-five pounds of chlorine. We constructed chlorine tank cars, each tank with a capacity of fifteen tons and a strength that could withstand a pressure of 500 pounds to the square inch. We also used for shipping sulphur monochloride a tank car originally designed for the shipment of chlorpicrin.

Total Monthly Capacity of Filling Plants on Date of Armistice (Stokes Shell, Drop Bombs, and Other Special Containers Not Included)

75-mm. shell (ultimate capacity)	2,400,000
4.7-inch shell	450,000
155-mm. shell	540,000
6-inch shell	180,000
Gas grenades	750,000
Smoke grenades	480,000
Livens drums	30,000

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CHAPTER XXV

GAS MASKS

DURING the spring and summer of 1917 two marked tendencies were to be observed in the fighting in France. One of these was the greatly increased use by both sides of poisonous gases and chemicals, frightful in their effect; the other the almost complete censorship that hid the knowledge of this tendency, not only from Europe, but particularly from the newest belligerent, America. The French and British governments, who then controlled all news from the front, feared, and perhaps with reason, that if the picture of gas warfare as it was then developing should be placed before the American people, it would result in an unreasonable dread of gases on the part of the American nation and its soldiers.

One year later, with tens of thousands of American troops facing the Germans, there was almost no censorship upon the details of fighting with chemicals. The mysterious gases of 1917 were then known to almost every reading individual in the civilized world. The once secret formulas were published in the technical journals. Noncensored photographs of defensive equipment were freely published, and masks and other paraphernalia were exhibited for the public interest. Except for secret plans for the future and the various surprises being prepared by one or more of the belligerents, the whole subject of chemical warfare had become an open book.

What had occasioned this change in policy on the part of governing authorities? The reason was that the American troops brought with them to France the best and most protective gas masks the world had seen; and they brought these with them by millions. Starting a mask-production effort in May, 1917, America turned out a total of 5,250,000 gas masks be-

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fore the armistice was signed, and sent more than 4,000,000 of them overseas. As to the quality of these masks, it is only necessary to say that they gave twenty times the protection afforded by the best German gas masks. In other words, we protected our soldiers against the poisons which Germany had brought into warfare, and protected them completely. No American soldier was ever gassed because of the failure of an American gas mask, and such gas casualties as did occur were due to the fact that the masks were not quickly enough utilized when gas was thrown over, or because the soldiers were unaware of the presence of gas. With such protection, there was no longer reason to fear that the frightfulness of chemical warfare would reduce American morale.

The production of gas masks was one of the most picturesque and successful phases of our entire war preparation. It engaged the attention of some of the principal chemical engineers of the country, and millions of men, women, and children in the United States contributed something to the success of the undertaking, if only by obeying the "Eat More Coconut" slogan or by saving peach stones for the benefit of the production of the charcoal essential to efficient gas masks.

The problem of making masks in such quantity and under such supreme demands for perfection was one which might well have staggered even manufacturers accustomed to large-scale operations. We started in with practically no knowledge whatsoever of the fundamental principles of a perfect mask. Yet the apparatus was as difficult to build as a rifle. It must, perforce, be made of perishable materials, and this fact brought the question of durability to the fore at the very start. It was evident that no chemical substances known in our past commercial life would give protection against the new poisons which had been developed in Europe. With the exception of phosgene and chlorine, the various war gases which had been brought out before our participation in the struggle were completely unknown in our trade or commerce and had existed only in our experimental laboratories. Then it was discovered that these toxins, as they increased in power, could penetrate

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the ordinary fabrics known in commerce; and this necessitated the creation of new types of materials to be used in the masks. Finally the increasing use of gases forced the soldiers to wear their masks for much longer periods than had been necessary at the beginning of gas warfare; so that the problem of comfort became one of great importance. All these basic considerations indicate to some extent the difficulty of the undertaking.

The chlorine, which floated in a pale greenish yellow cloud down upon the defenseless Canadian troops at Ypres, with such terrible effect upon the men, was, as has been said, the first war gas so used. Chlorine, though easy to obtain, the principal source of supply being common table salt, was, from the standpoint of strategy, far from being the ideal gas of warfare. Troops could be quickly and easily protected from it. But even so, only lack of faith in their new weapon prevented the Germans from winning the war with it then and there. Had they brought into the fighting a sufficient supply of this chlorine, they might have gassed their way to Paris in short order. Actually, they brought to the line an almost negligible supply, and they themselves were insufficiently protected to go through their own gas and follow up the attack. By the time they were able to renew gas warfare the French and British had equipped themselves with masks which were sufficient to protect men against chlorine. Thereafter, the tendency was toward new and strange gases which were heavy in weight and highly toxic in their physiological action. This development led to new, slightly volatile liquids, the so-called mustard gas being the best example. Mustard gas (properly called dichlorethyl sulphide) is similar to lubricating oil in many of its physical characteristics, but smells like ordinary mustard. Ground soaked with the mustard gas remains impregnated for days, the vapor rising continually.

A perfect mask is one which will remove completely every trace of gas or poisonous vapor before the air can reach the eyes, nose, or mouth of the soldier. The first masks adopted by the Allies were simply gauze pads saturated with neutralizing chemicals. These became unsuitable as soon as new varieties

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of powerful poisons were brought out. The mask development thereafter progressed to the box respirator type. This consisted of a mask or helmet connected to a box filled with absorbing and neutralizing chemicals which purified the air for the mask wearer. This was the type of respirator in use to the end of the fighting.

It is quite clear to us now that only such a mask could be efficient in chemical warfare, but in the early part of 1917 the matter was not clear either to us or to the Allies. The first requisitions from the A. E. F. called for masks of two types, each soldier to be supplied with one of each. The reserve mask was to be of the gauze type and the regular mask of the box respirator type, affording protection from the more powerful poisons that were then just coming into use. We wasted considerable energy at the beginning in our attempt to produce both types. Eventually, however, when we were just ready to start manufacturing the gauze-type mask, orders came to abandon the effort, for it was even then patent that our soldiers must be prepared at all times to withstand all gases.

The box respirator equipment, the general principle of which was finally adopted by all the nations at war, fell into two classes. In a single-protection mask, the wearer breathed air from inside the face piece, so that any leakage around the edges of the face piece would result in a casualty when the wearer was in a strong concentration of gas. The other sort, known as the double-protection mask, consisted of a gas-tight face piece, similar to that of the single-protection mask. In this type, to guard against any possible leakage around the edges between the mask and the wearer's skin, the breathing system was sealed away from the air inside the face piece by means of a rubber mouthpiece and a nose clip, the wearer inhaling through the mouthpiece.

The United States and English double-protection masks consisted of eleven principal parts, as follows:

1. A knapsack slung from the shoulder or neck. This contained the canister and a pocket for storing away the mask when it was not in use.

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2. A metal canister in which were contained the absorptive neutralizing chemicals.

3. A flexible hose reaching from the canister to the face piece.

4. A flutter, or exhalation, valve, which opened when the wearer exhaled his breath and closed when he inhaled, thus bringing the inhalation through the canister but allowing the exhalation from the lungs to pass out without polluting the chemicals of the canister.

5. The face piece, or hood, fitting snugly around the edges and covering the eyes, cheeks, lower forehead, nose, mouth, and chin.

6. The eyepieces, or lenses, through which vision was maintained.

7. An elastic harness for the head, to hold the face piece in place.

8. A body cord to tie around the chest and hold the knapsack firmly, so that the mask could be seized in both hands and pulled out of the knapsack.

9. A metal flange connection or angle tube which carried the hose through the face piece to the mouthpiece.

10. A rubber mouthpiece through which the wearer breathed and which helped to hold the mask in place.

11. A wire nose spring and rubber nose pad to hold the nostrils shut and force breathing through the mouth.

The first order for gas masks was issued on May 16, 1917, when the Chief of Staff asked the Surgeon General to supply 1,100,000 masks before June 30, 1918, or within about one year. Meanwhile 25,000 masks were needed at once in order to equip General Pershing's first division, then about to sail overseas. There was but one man in the Army who knew anything at all about the subject and who could even attempt to produce this quantity in three weeks. This was Major (later Colonel) L. P. Williamson, of the Surgeon General's Department, who had been spending some months at the Army War College at Washington studying, as a side issue, such papers on gas warfare as came from abroad. It was due to his knowl-

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edge and the volunteer staff of the Bureau of Mines that we were able to begin the actual manufacture of masks within a few days after the requirements were fixed, and actually to turn out 25,000 masks in but little more than three weeks' time.

Major Williamson's first step was to consult with Dr. Van H. Manning, the Director of the Bureau of Mines, and with his assistant, Mr. G. A. Burrell. Since February, 1917, the Bureau of Mines had been experimenting with gas masks and had built up a corps of scientists for this work. Within this organization was Mr. Bradley Dewey, a chemical engineer, who, though then director of the research laboratory of the American Sheet & Tin Plate Company of Pittsburg, had been loaned to the Bureau of Mines. To Mr. Dewey was turned over the job of directing the production of the first 25,000 masks for the American troops then sailing. To produce 25,000 gas masks in three weeks meant to compress England's two years of experience into twenty-one days. The military authorities of this country at that time could plead entire ignorance of the qualifications of an efficient gas mask. The prevailing idea seemed to be that you could go out into the market and buy them by hundreds of thousands, as you could buy Hallowe'en masks. But this was not any ordinary poison which we were to fight. These powerful chemicals attacked the human tissues as acid would. As the result of the effort, we did supply masks to the first division going overseas in July, but the masks were inferior to the British masks and were quickly replaced in France by British equipment. It was not until the following January that we developed an apparatus which we regarded as suitable to be subjected to the supreme test of battle.

To indicate some of the difficulties overcome between May and December, 1917, we note here certain of the qualifications of an effective mask.

In the first place, the face piece must fit perfectly: it must not leak gas around the edges. It must fit into the hollows of the temples and give the jaws a free space in which to work, and yet not slip back and press against the Adam's apple. The

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pressure of the mask on the forehead must come above the supra-orbital nerves, which are just above the eyebrows, or else intense headaches will result from a few moments' wear. Moreover, to fit all faces and heads, several graduated sizes of masks are required. We first attained the gas-tight fit with a padded band around the edge of a flexible rubber-cloth face piece. Later we developed a thicker, stiffer face piece, but maintained a gas-tight fit by the elasticity of the face piece and the head harness.

Then the material of the face piece must be gas-tight in itself. At first we manufactured a fabric made by spreading rubber on cotton sailcloth; and, after testing it, we found that the smallest molecule known, that of hydrogen, would not pass through it in large amounts. This seemed to be a suitable fabric, until tested by the newer gases. Then we found that some of these gases were soluble in rubber compounds and could dissolve their way through thin rubber so quickly that the face-piece cloth offered practically no protection at all. Another difficulty with the rubber fabric was that it was likely to absorb and hold certain of the poisons, so that a man might be gassed by the mask itself. The rubber companies, principally at Akron, Ohio, experimented continually until they discovered a coating that would not only withstand gas concentrations for a sufficient time, but would also aërate promptly and lose as much gas as it had absorbed.

The eyepieces or lenses offered another problem. Celluloid is strong, but it is not so transparent as glass. It ignites easily and is easily scratched. Glass is ideal in transparency and will not burn, but it is fragile. It was evident that we must provide eyepieces which would not break easily, for even as slight an accident as the breaking of a lens might cost a soldier his life by admitting concentrated gas to the mask. A material known as triplex glass had been experimentally made. This consisted of a thin celluloid strip sandwiched between two layers of glass, all three welded together. This glass would not splinter, and, even if cracked or broken, would still be gas-tight. However, this had never been made in quantity, and it was neces-

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sary to work out many kinks and to start a large plant to provide the necessary millions of lenses.

Another problem to be solved was the tendency of the eyepieces to dim, particularly in cold weather, as the wearer breathed moist breath into the mask. The answer to this problem was a soapy compound which put a slippery surface on the glass and obviated the droplets of mist. The first masks were also equipped with deep plaits so that the wearer could wipe off the lens with the interior of the face piece itself. The final development (the invention of a Frenchman by the name of Tissot) was to bring the cold air into the mask so that it flowed directly against the lenses and evaporated any condensed moisture. This kept the lenses clear under all ordinary circumstances.

It was evident that the metal tube passing through the face piece must not contain pinholes and must be able to stand rough handling without pulling loose. The harness must maintain a gas-tight connection between the wearer's face and the face piece, but not at the cost of pain or chafing of the face or head. The flutter valve must fit with absolute tightness and must work perfectly and instantaneously at all times. The flexible hose leading from the canister to the face piece must be strong and without flaws or leaks, yet flexible in the extreme. A stiff hose would be likely to swing and displace the face piece whenever the wearer moved. The mouthpiece must be comfortable and must be so designed as to prevent irritation to the gums or lips; yet it must be reinforced so that the soldier could not, in his excitement, bite down and shut off his air supply.

The canister must withstand corrosion and must be gas-tight. Smooth-sided canisters could not be used, for the gas would slip up the sides without coming in contact with much of the chemical filling. The sides of the canisters were therefore ribbed so that the charcoal and other ingredients, working into these ribs, baffled the gas and threw it out into the body of the chemicals. The canister, moreover, must be equipped with a perfectly working check valve which would stop exhala-

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tion through the canister and force the air to pass out through the flutter valve.

The web sling of the knapsack must not curl and chafe the neck or shoulders of the wearer. The knapsack must be waterproof and must have easily and quickly workable fastenings.

The canisters were filled with charcoal and with cement granules. These were crushed into carefully sized small bits about the size of a pinhead and packed into layers in the canisters. The air could pass through them easily and the particles of both substances absorbed gas. The chief qualitative requirements for the carbon and the cement were long life and great activity.

Of the canister ingredients the charcoal offered the more difficult technical problem. It had long been known that charcoal was highly absorptive of certain gases, but except in rare instances no thorough study had ever been made of the subject. It was evident, however, that the greater the amount of charcoal, or carbon, that could be packed into the canister and still allow the free passage of air, the greater the amount of gas that would be absorbed. Therefore a search was made for carbon existing in the natural state in the most compact form. This search is described later.

Each canister also contained concrete granules in a definite proportion to the carbon pieces. These granules were made of cement mixed with strong alkalies and oxidizing agents, to digest the poisons as they passed through the canister.

It will be seen that the manufacture of good gas masks was a highly technical undertaking, one calling for the best talents of eminent men of science. The mask was not something that could be improvised on the spur of the moment, but each part of it must be worked out after the most painstaking research. The Gas Defense Division of the Chemical Warfare Service never at any time approved a type of mask which its own officers or men did not themselves wear in the most deadly concentrations of gas.

To get back to the chronological order of development: On May 21, 1917, the making of the first 25,000 masks was

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started with frantic haste; though, as it later developed, there was no need for such an effort, since there were available in England and France plenty of masks for the first American troops. Working to produce in the shortest possible time some sort of protection for the first overseas division, the officers in charge were forced to adopt methods which, had they been followed throughout the manufacturing program, would have been extremely costly. There was no time then to stop and study the problem, either here or abroad. Before the end of June, 20,088 masks had been started overseas, and 5,000 more were ready a little later. The most that can be said for this effort was that it gave our officers the experience which was the groundwork of the solid development later on.

The production of these first 25,000 masks called upon the services of various manufacturers. The assembling of the masks was conducted by the American Can Company, at Brooklyn, New York. The B. F. Goodrich Company, of Akron, manufactured the face pieces with the eyepieces inserted, also the connecting hose, the check valve of the canister, the flutter valve, and the rubber mouthpiece. The American Can Company produced the canisters. The Day Chemical Company, of Westline, Pennsylvania, gave the charcoal its first burning. The Ward Baking Company, of Brooklyn, patriotically baked the charcoal—to activate it—in their bread ovens, free of charge. The General Chemical Company, of New York, supplied the soda-lime granules. The Doehler Die Castings Company, of Brooklyn, manufactured the angle tubes. The Simmons Hardware Company, of St. Louis, produced the waterproof knapsacks. The Seaver-Howland Press, of Boston, printed the cards of instruction that went with the mask outfit; and the Beetle & MacLean Manufacturing Company, of Boston, printed the record tags.

Though Major Williamson was formally in charge of this emergency work, he requisitioned the masks from the Bureau of Mines, which took actual charge of the first contract. Following this, on August 31, 1917, the Gas Defense Service of the Surgeon General's Department was established by official

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EMPLOYEES AT GOVERNMENT GAS MASK FACTORY

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MASKS WORN IN WORLD WAR
(American Masks on Men of Rear Line)

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SEWING ROOM IN MASK FACTORY

Photo from Chemical Warfare Service

ASSEMBLING GAS MASKS

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order, and Mr. Dewey, who had been working as a volunteer in the Bureau of Mines, was commissioned major and put in charge.

The next step was to prepare for the permanent development and manufacture of gas masks. Contracts were let for the manufacture of 320,000 component parts of masks as we then knew them, and a price was fixed for the assembling of the entire original requirement of 1,100,000 masks. The assembling contract went to the Hero Manufacturing Company, of Philadelphia, which remained until the end of the war the sole private contractor for assembling our gas masks.

The spirit of coöperation and desire to serve the Government was evident from the start. The B. F. Goodrich Company had been the only producers of the rubber parts of the first 25,000 masks. In this original contract it had gained valuable technical and cost knowledge; but in order that the Government might not be limited to one source of supply for such parts, the Goodrich Company voluntarily imparted to the Goodyear Tire & Rubber Company and to the United States Rubber Company the information that would enable them to bid intelligently for portions of the work. This was a distinct departure from the usual practice in competitive industry.

All during the fall of 1917 and early winter of 1917-1918 the development of the mask continued, the government experts working hand in hand with private contractors. Because of the newness of this sort of manufacture and the wide variety of unusual articles required, entailing in some instances the actual creation of hitherto unknown commodities, the Government at all times was required to act as the procurer of raw materials for the masks. In this period of development America designed her own typical mask—a gradual evolution, but one which, though based on the British design, arrived at a perfection hitherto unknown in warfare.

The triplex glass used in the eyepieces was a patented commodity produced only in one small factory in Philadelphia. It was necessary to expand the facilities for the production of

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this necessary material. Meanwhile some of the men engaged in the work had improved the eyepiece by providing it with an aluminum mounting. But this very improvement brought embarrassment to the work, for the Akron rubber contracts had provided for eyepieces inserted in the fabric itself, and to apply the aluminum frame brought about a radical change in the manufacturing methods at the rubber factories.

There were also many other problems that had to be solved before our authorities were satisfied to go ahead in quantity production. There was, for instance, the matter of rubberizing the face-piece fabric. Two methods of rubberizing cloth were in use. The first was to roll out a thin sheet of rubber and then press it into the cloth fabric by running the whole thing under heavy rollers. This was known as the calender method. The other method, called the spreader method, was more intricate. In this process the sailcloth, tightly stretched, was carried around a roller. A few thousandths of an inch above the roller was a knife blade extending from edge to edge. The rubber compound in liquid form was then fed upon the roller in such a manner that a thin film of it was pressed under the knife blade and upon the cloth on the roller. The rubberizing method finally adopted was a combination of the calender and spreader methods. The rubber was applied green to the cloth. The subsequent curing process was highly important. If it were too short, the rubber would be sticky and would pull off the sailcloth too easily. If the rubber were overcured, it would crack and split.

Nothing short of absolute perfection in every part would do, for the slightest imperfection anywhere was likely to cost a man his life. Not only did we install 100-per-cent inspection at the various producing plants, but we also constructed laboratories for putting the materials through the most elaborate and exhaustive sorts of control tests, and then reinspected the parts at the assembly plants, both before and after the assembly. All the rubber used was continually sampled and analyzed in the laboratories. The tensile strengths of all fabrics were determined by standard destructive tests.

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We also tested the adhesion of the rubber coating by standard chemical methods and worked out flexibility tests for the breathing tube. After all the factory-inspection and material-control tests, the masks themselves were sampled and worn in highly toxic atmospheres. In this work thousands of our masks were worn by the officers and men of the Gas Defense Division in concentrated atmospheres of the most deadly gases. For such work we constructed testing rooms whose atmosphere could be completely exhausted and changed in ninety seconds. The efficiency of canisters was tested either by the lungs of the inspectors or by mechanical breathing into telltale solutions.

The story of the carbon (charcoal) which went into the American canister is one of the most interesting phases of the whole undertaking. Investigations carried on by the research staff of the National Carbon Company, aided by a clue from the University of Chicago, led to the selection of coconut shell as a raw material. Any carbon absorbs a definite number of times its weight of gas. Therefore the densest carbons will be most efficient, volume for volume, as gas absorbers in a given space. Coconut shells and other nutshells were found to be the most compact form in which carbon exists in nature in commercially practicable quantities, being considerably superior in this respect to anthracite coal and to such woods as ironwood and mahogany. Another essential for charcoal used in the canisters was that it must be so hard that it would not crumble easily and produce dust that would clog up the air passages and prevent easy breathing through the canister. Coconut shell fulfilled both these conditions better than any other known material.

Further study by the National Carbon Company, backed up by wonderful large-scale development work, paid for and carried out by the National Electric Lamp Association under the direction of their Mr. F. N. Dorsey (who later became Colonel Dorsey and Chief of the Development Division of the Chemical Warfare Service), gave us the details of a new process for treating the charcoal to make it absorptive. After the original burning of the nutshells or other carbon materials,

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the resulting carbon was given a second highly specialized heat treatment, and this activated it until it had a powerful affinity for gas. Such carbon, made from nutshell material, would almost instantaneously absorb 150 times its own volume of chlorpicrin, one of the most deadly of the war gases.

Nor must it be supposed that investigation of carbons stopped with these experiments. In the search for the ideal carbon we experimented with almost every hard vegetable substance known. Literally hundreds of kinds of carbon were tested. Next to coconut shells, the fruit pits, several common varieties of nuts abundant in the United States, and several tropical nuts were found to make the best carbon. Pecan nuts, and all woods ranging in hardness from ironwood down to ordinary pine and fir, were found to be in the second class of efficiency. Among other substances tested were almonds, Arabian acorns, grape seeds, Brazil nut husks, balsa, osage oranges, Chinese velvet beans, synthetic carbons, cocoa bean shells, coffee grounds, flint corn, corncobs, cottonseed husks, peanut shells, and oil shale. Many of these substances might have been used in an emergency, but none of them would produce carbon as efficient, volume for volume, as that of the coconut shells and other hard nuts.

Some idea of the scale of the American mask production may be seen in our requirements for coconut shells. In our survey of raw materials we included the entire coconut resources of the world. Such figures were relatively easy to obtain, because the copra or dried-coconut-meat industry is an important one, particularly in southern Asia and the South Sea Islands of the Pacific. Ceylon was the greatest single source of coconuts, 2,300,000,000 nuts being gathered there annually. British India was next with 1,500,000,000 nuts. Our own Philippine Islands were third, with an annual production of 900,000,000 nuts. Then followed in order the Dutch East Indies, British Malaya, French Indo-China, Siam, and the Pacific archipelagoes, the total production of the Orient being 7,450,200,000 nuts annually. This was a supply that would provide 4,000 tons of coconut shells every day. The total pro-

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duction of coconuts in Central America, the West Indies, and the Caribbean coast of South America amounted to 131,000,000 nuts annually, or a supply of seventy-five tons of shells daily.

When we began to build masks our demands for carboniferous material ranged from forty to fifty tons a day of raw material; but by the end of the war, thanks to vastly increased mask requirements, we were in need of a supply of 400 tons a day. This demand would absorb the entire coconut production of the tropical Americas five times over. It was equal to one-tenth the total coconut production of the Orient. Since transportation from the oriental countries was out of the question on the scale demanded by our mask program, it was evident that we were likely to be seriously embarrassed by the lack of raw materials; and indeed at no time before September, 1918, did we have on hand a reserve supply of shells and other charcoal materials that would last for more than a few days, though at no time after the start was the actual output of masks retarded by lack of these materials.

In building up our supply of coconut shells we naturally turned first to the resources in the United States. America normally consumes fresh coconuts at a rate sufficient to supply about fifty tons of shells daily. The war restrictions on the use of sugar had the effect of cutting down the consumption of coconuts, used largely in candy and cakes, and consequently one of our efforts was to increase by widespread propaganda the use of coconut. The "Eat More Coconut" campaign more than doubled the American consumption of coconut in a brief space of time; and the fifty tons of shells daily which had been the original supply grew in volume until in October, 1918, with the help of importations of shell, we averaged about 150 tons a day, exclusive of the Orient.

The first heating of coconut shells to make charcoal reduces their weight 75 per cent. Therefore it was evident that we could most economically ship our oriental supply in the form of charcoal produced on the other side of the Pacific Ocean. For this purpose we established in August, 1918, under the

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direction of an officer of the Chemical Warfare Service, a charcoal plant in the Philippine Islands. From this plant, agents were sent to Ceylon, India, Siam, and other oriental countries to purchase enormous supplies of nutshells. This work was only gaining momentum when the armistice was declared. As it was, the Philippine charcoal plant actually shipped over 300 tons of coconut shell carbon to the United States, and had on hand ready for shipment, on November 11, 1,000 tons.

The method adopted in the Philippines was to burn the shells in long, shallow trenches. As soon as the smoke had disappeared and the flames came clear and lambent through the incandescent mass, the bed of coals was smothered by means of galvanized-iron lids thrown over the trenches. It is interesting to note that the coolies hired by the Chemical Warfare Service in the Philippines would not work at charcoal burning more than a few hours each day, because they declared that the heat from the pits would give them tuberculosis and other lung troubles.

Meanwhile agents and officers of the Gas Defense Division were searching the tropical regions of Central and South America for other nuts valuable for this purpose. The best of these was found to be the cohune or corozo nut. These nuts are the fruit of the manaca palm tree. They grow in clusters, like bananas or dates, one to four clusters to a tree, each cluster yielding from sixty to seventy-five pounds of nuts. Cohune nuts grow principally on the west coast of Central America in low, swampy regions from Mexico to Panama, but are also found along the Caribbean coast. Before the war created a demand for cohune nuts, none of them had ever been imported commercially in this country, although it is understood that France had a prewar commercial use for them.

The chief virtue of the cohune nut from our point of view was its extreme thickness of shell, the kernel of this large nut, which is three inches or more in length and nearly two in diameter, being relatively small. We were importing cohune nuts at the rate of 4,000 tons a month at the time of the armistice. A disadvantage in the use of cohune nuts was that their

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husks contained a considerable amount of acid which rotted the jute bags and also caused the heaps of nuts to heat in storage. The fire department at the Chemical Warfare Service nut storehouse at Astoria, New York, was kept busy putting out spontaneous blazes in the storage piles of cohune nuts. We also sent agents to West Africa and there arranged for the shipment of some hundred tons of palm nuts a month.

A third source of tropical material was the ivory nuts used in considerable quantities in this country by the makers of buttons. In the button factories in this country there is considerable waste of this nut material, amounting to four or five hundred tons a month, this waste including the nut dust, which was useless to us and had to be screened out. The price of ivory nut waste was high, because of the use of this material in the manufacture of lactic acid. Nevertheless, we used a considerable quantity of it.

Another great project of securing carbon supplies was undertaken in this country. In the search for fruit pits and for domestic nuts it was found that the quantity of apricot pits, peach pits, cherry pits (largely from the canning industry), and walnut shells on the Pacific coast amounted to 23,600 tons annually. We arranged for the whole Pacific coast supply of these commodities and converted a part of a San Francisco plant of the Pacific Gas & Electric Company into a plant for the preliminary carbonization of a hundred tons a day of these materials. The next step was to turn to the consumers of the country and ask them to save their peach and apricot stones, their prune, plum, and olive pits, their date seeds, cherry pits, butternut shells, Brazil nut shells, and their walnut and hickory nut shells. The work of securing these and advertising the Government's need to the public was turned over to the American Red Cross. There was some question at the start whether the charter of the Red Cross would permit it to undertake such a war activity; but since it was determined that this was purely a defensive operation, the legal forces of the Red Cross decided that the organization could go into a campaign of this kind. "Help us to give him the best gas

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mask." That was the slogan which was carried on the posters, and it caught the attention of almost every person in the United States. More than 1,000,000 pieces of literature were distributed. The Red Cross established 163 collection points, and collection barrels appeared on the streets of practically every community in the United States. The Junior Red Cross, the Food Administration, and the Department of Agriculture gave valuable assistance. The Boy Scouts organized nut-gathering parties. The governor of Massachusetts proclaimed November 9, 1918, to be gas mask day for the collection of carbon material, and twenty-eight other states fixed gas mask days in November. Two reels of motion pictures were shown through the country. Journalists aided the campaign in newspapers and magazines. One Oklahoma town took a day off *en masse* and gathered a whole carload of nuts.

This campaign, which started September 13, 1918, was abruptly cut short on the 11th of November, so that it is impossible to state the exact result of it. Many of the scheduled shipments of nuts and fruit pits were canceled, and the supplies found their way into fuel bins. However, at one time there were on the rails, *en route* to the carbon plant at Astoria, 100 carloads of materials supplied by the patriotism of the American people. It was estimated that some 4,000 tons were collected in this brief period, exclusive of the material from the California canning industry.

The procurement of the nuts, however, was but the first step in the production of carbon for use in our mask canisters, for after charcoal is first burned its pores are still filled with various impurities which may be summed up by the word "tar." When the charcoal was given a second heating, under careful temperature regulation, this tar was burned out, whereupon the charcoal became much more active in its absorption of gas. In fact, properly activated charcoal is more than absorptive—it is catalytic in its action toward the gaseous poisons used in the war, not only absorbing them, but hastening their breakdown (digestion) into less injurious substances.

The activating of charcoal offered at the start considerably

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more of a problem than making charcoal, since activating had never before been conducted on a commercial scale. Two months of experimentation showed us that the best distillation of shells and pits for charcoal was that conducted in illuminating-gas-making retorts. The activation thereafter had to be done in special equipment which permitted nice regulation of temperature. The Government eventually spent more than $1,000,000 in a charcoal-activating plant, providing for America the best protection known to science against the poisons which Germany had introduced into warfare.

The cement granules which also had to go into the canisters supplied another problem. We originally used a special soda-lime for this material, but obtained a satisfactory product only after Major H. W. Dudley, R.E., came to America as our British adviser and brought to us the British granule formula. The basis of this cement was lime, to absorb gases of an acid nature. Portland cement was used, to give hardness and prevent disintegration and the formation of dust in the canister. Then infusorial earth was added, to make the compound porous in texture. A little sodium hydroxide was put in, to increase the alkalinity of the mixture. Finally there was an infusion of sodium permanganate, a powerful oxidizing agent, added as a precaution against arsine. Arsine and arsenical compounds were difficult to use in warfare, but the Germans had introduced them to some extent, justifying us in adding this protection. In making the granules the sodium permanganate solution was mixed with the cement. The mixture was roughed out into slabs, allowed to set for three days, dried, ground up, screened to the proper size, and packed in drums for future use.

As has been noted, the charcoal and cement were packed in the canister in alternate layers. The cement had the virtue of working while the carbon slept—that is, the carbon was active when there were gases present to be absorbed, but the cement kept on thereafter, digesting the gases which had been absorbed by the charcoal. The cement was not quick in action, but it had a remarkable capacity for consuming some poisons.

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To return to the chronological development of manufacturing facilities: After we had placed the contracts for the first 1,000,000 masks in the early fall of 1917, we began looking around for facilities for producing carbon and cement in the quantities which we should need in the near future. We found at Astoria, the district near Hell Gate at the junction of the East River and Long Island Sound in New York, the large gas works of the Astoria Light, Heat & Power Company, perhaps the largest illuminating-gas plant in the world. This was a subsidiary of the Consolidated Gas Company of New York, which concern readily agreed to turn over to the Government some of its retorts and to permit the construction of a government-operated plant on its grounds. We might have been seriously delayed in the production of gas masks but for the extraordinary and indefatigable efforts of Mr. W. Cullen Morris, chief construction engineer of the Consolidated Gas Company, and of Mr. Addicks, its vice-president. It was due to Mr. Morris that a $150,000 granule plant was constructed, heavy complicated equipment installed, and operations started, all in the short space of thirty days.

Let us now go back to the history of actual mask production. At the start it was estimated that the Hero Manufacturing Company, when it had reached full capacity, could assemble and turn out 6,000 masks a day. The fuel shortage and the railroad congestion of the late fall and early winter of 1917-1918 hampered our supplying the Hero Manufacturing Company with parts, until the mask production, averaging 2,430 a day as it had in November, dwindled to 1,500 a day in December. The Goodyear Company at Akron had meanwhile established its Akron-Boston motor truck line. This was put at the service of the Gas Defense Division for hauling various supplies from both Akron and Boston to the assembling plant at Philadelphia. Sometimes the trucks would be blocked in snow in the mountains of Pennsylvania and the patriotic citizens of the community would get out with shovels and work until the supplies again started on their way.

All the masks produced in the fall of 1917 were regarded

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as experimental and not yet up to the standard of masks which we were willing to supply for actual service at the front, and not one of them was exported. The entire 1917 production, after the first order of 25,000, was sent only to the training camps in this country. By January 8, 1918, we were producing masks which we were willing to put into actual service, and on that date the manufacture of masks for export was started. In January we exported 54,000 masks, 16,000 fewer than the schedule which we had set for ourselves. But by February 20 we had wiped out this deficit with a little over, for our schedule by that date called for the production of 141,000 gas masks, and we had produced 142,000.

Late in the fall of 1917 the requirements of the Expeditionary Forces were reanalyzed in the light of information gathered abroad and in accordance with the new military program. Requirements were multiplied almost fourfold. Let us see how these requirements were met, and what difficulties were solved in the course of the effort.

Experience had already shown that for many reasons the Government needed its own mask factory, where improvements could be adopted as soon as made and where inspections and the storage of parts could be more centralized than in private plants. With the necessary expansion then confronting us, any other policy would have meant making face pieces in half a dozen or more private plants, all starting at once with organizations untrained for this work. This would have been fatal, for even with the Goodyear and Goodrich companies manufacturing face pieces in Akron and the Kenyon Manufacturing Company in Brooklyn, we found it most difficult to maintain uniform standards in all the plants. As new points came up, it was constantly necessary to interchange inspection *personnel* and to send men from one plant to another to teach manufacturing wrinkles. Such practices consumed more *personnel* than we could train in the time available. Moreover, it was impossible under the conditions that we were then facing to build up more than barely adequate supplies of gas mask parts and such raw materials as special fabrics. To have

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operated many more face-piece plants would have meant still further to divide these stocks of fabrics, elastic tape, and the like. To keep each of these plants properly stocked under the existing traffic conditions would have been impossible. A big central gas-defense plant was the only solution of our difficulties.

The order approving the establishment of the gas-defense plant was signed by Secretary Baker on November 20, 1917. The officers of the Gas Defense Division found in Long Island City, not far from the new chemical plant at Astoria, a group of modern concrete factory buildings which had been put up in this newly developed section by several different concerns, among them the Ford Motor Company, the Goodyear Tire & Rubber Company, and the National Casket Company. One of these buildings, known as the Stewart Building, was taken over by the Government and modern machinery was installed. Mr. R. R. Richardson of Chicago was appointed plant manager with a salary of one dollar a year. He quickly set to work organizing the factory and its staff. On January 9, 1918, the first few factory operators were hired. Five days later the executive offices at the plant were ready for occupancy. The plant grew apace. One by one the other buildings were absorbed and added to the establishment—first the Goodyear Tire & Rubber building, then the National Casket building. Next a long storage building was built between the Stewart and the Goodyear buildings. Runways were built which connected the various buildings, and finally, in July, the Ford Motor building was taken over and connected to complete the group. Thus, by the summer of 1918, we occupied five large buildings, with a total of over 1,000,000 square feet, or twenty acres, of floor space, interconnected to make the gas-defense plant.

Of the 12,000 employees in this plant, 8,500 were women. Endeavors were made to hire, so far as possible, those who had near relatives with the American Expeditionary Forces. The degree of care required in the manufacture of masks was beyond anything known in normal industry, and

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Photo from Chemical Warfare Service

MOUNTAIN OF APRICOT PITS AT SAN FRANCISCO CARBON PLANT

Photo from Chemical Warfare Service

FIVE THOUSAND TONS OF PEACH STONES FOR MASK CARBON

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Photo from Chemical Warfare Service

THE AMERICAN K-T MASK

Photo from Chemical Warfare Service

TYPE OF MASK CHIEFLY WORN BY A. E. F.

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we rightly believed that this personal interest in the work would bring about greater care in manufacture and inspection. Since the factory was working at top speed, a great deal of attention was paid to welfare work. Women employees were given twelve-minute rest periods both in the morning and the afternoon, and completely furnished attractive rest and recreation rooms were set apart for them.

The plant was unique in more than one respect. At the very start it attempted the supposedly impossible, for it combined in its staff and in its working organization civilian and military *personnel*. The manager was a civilian, the assistant manager was Lieutenant Colonel Coonley. Below them, on the next tier of the organization, were army officers in charge of several departments and civilians in charge of others. Throughout the plant were certain groups of women workers or inspectors in charge of civilians. The arrangement worked out well and the whole organization pulled together as one team, without reference to civilian or military status. Again, at the start there was laid down a policy of inspection at every single stage of manufacture. The incoming parts, though already inspected at their source, were reinspected and retested. After every operation in the manufacture of the face piece there came an inspection by specially trained women set apart from the operators. Again, there was a special control inspection. After the face piece was finished and when assembly was complete, the entire mask went to a final inspection, where it was looked over by several trained women, who worked in dark closets and inspected the face pieces over a bright light to make sure that no pin pricks had been made, either maliciously or otherwise. Furthermore, whenever there was an inspector there was a system of checking his or her accuracy, for 5 per cent of every inspector's work was periodically selected at random and checked over by other inspectors. Hand in hand with this rigor went many of the latest developments of factory operation. The best machinery was employed, conveyors were used wherever possible, and, whenever changes in the size of the operation or the design

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of the mask made it advisable, the factory was at once rearranged in order that the flow might always be orderly and continuous.

From all this the reader might judge that the operation, lasting as it did for only a little more than eight months, was a costly one. But it was not. A well-ordered and accurate cost system, kept from the very start in accordance with the best practices of factory accounting, showed that, after charging in all equipment changes and overhead expense, the plant made complete masks which cost the Government about fifty cents apiece less than it cost to get complete masks by purchasing parts and assembling them under private contracts.

Along with this manufacturing development went the building up of an elaborate procurement force charged with the responsibility of providing parts to be assembled at the gas-defense plant and the plant of the Hero Manufacturing Company. This section faced a hard and intricate task, but though there were instances in which a shortage of parts temporarily slowed down production, these were remarkably few. Many were the difficulties of buying new parts; many of the parts were the product of elaborate die work; die makers in the country were overworked. Specifications had to be written, checked, and approved, and a field inspection first had to be organized and trained so that the product from all the different plants could be relied upon as satisfactory for the assembling plants. And this problem was still further complicated by ever-recurring changes in design, made necessary as improvement followed improvement. Officers had to be trained in a day and then sent out to train inspection corps in manufacturing plants in many parts of the country. Inspection and procurement detachments were maintained in most of the eastern industrial centers. There were over a hundred enlisted men and nine officers in Akron, thirty enlisted men with six officers in Boston, and men and officers in over sixty cities. Here again the civilian and the army officer worked hand in hand. Mr. Robert Skemp, a volunteer civilian from Pittsburg, was in charge of this procurement, reporting to Lieutenant Colonel Besse and direct-

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ing an organization made up almost entirely of officers and enlisted men.

The March output of masks was 183,000; that of April, 363,000; May, slightly less than this figure; June, 504,000; July, 671,000. Between January 1 and November 11, 1918, we built in all more than 5,000,000 gas masks.

In February, 1918, shortly before the German drive began, we received requisitions for sample lots of oiled mittens and oiled union suits as protection against mustard gas; also for chloride of lime to neutralize poison-impregnated earth. In their March drive the Germans used gas in much more protracted concentrations than before. Originally the masks had been worn only during the sporadic gas alarms, and then only for a brief period at a time. The double-protection mask which we had been building had been admirable in its day, but it was no longer adapted to the sort of use to which it must now evidently be put. In long-continued wear the mouthpiece would irritate the gums and lips of the soldier, and the face-piece band would cause excruciating headaches after a few hours. It had now frequently become necessary for men to wear their masks for eight hours at a stretch. The word "discomfort" is a weak description of the feelings of a man wearing one of our masks for that period.

Our authorities in France decreed for a single-protection mask and more comfort, even at the sacrifice of a little safety. The result of these new conditions, together with the establishment of closer relationship with our Expeditionary Forces through a visit of Colonel Dewey to France, was the determination to build masks in this country which should give the protection of the masks which we had been turning out and at the same time be comparatively comfortable. There had been brought out in France a single-protection mask—that is, a mask in which the inlet tube entered directly into the space between the mask and the face, with the orifices so arranged that the fresh air was drawn across the eyepieces. This was known as the Tissot mask. The principle of the Tissot was correct so far as comfort was concerned, since it did away

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with the irritating mouthpiece. Its chief drawback was that it was made of pure gum rubber, dangerously thin. We took the Tissot and endeavored to produce a mask of its type which should be gas-tight and yet rugged. In this work we experimented on hundreds of subjects to determine face and head sizes and shapes. It is interesting to note in this connection that the size of a man's face has nothing to do with the size of his head: large heads with small faces and small heads with large faces occur not infrequently.

We made two developments of the mask without mouthpiece or nose clip. Both were ready for field tests in August, 1918. The one produced in Akron and assembled at the Philadelphia contracting plant was known as the Akron-Tissot, or Type A–T. At the start of operations in Long Island City Mr. Waldemar Kops, of New York, a manufacturer of corsets, came to the Government asking for an opportunity to do his part in the war. He was assigned to the gas-defense plant, and later, with the commission of major, took charge of the gas-defense Long Island laboratories. Major Kops had had no experience with gas masks until he came to the gas-defense plant, but his experiments soon led to an improvement in the design of the Tissot mask. It was called the Type K–T mask—the Kops-Tissot. It possessed much of the protective efficiency of the old uncomfortable mask, the cut of the face piece ensured a gas-tight connection with the head, it was relatively comfortable, and it was durable. Only a few hundred thousand were produced, though the latest model was scheduled for enormous production beginning in December, 1918.

The call of the Allies in the spring of 1918 for American troops in numbers as great as the ships could carry to France resulted in still further increases in our mask requirements. At the height of the drive we were making over 40,000 masks a day. Approximately 35,000 employees were engaged in the manufacture of various gas mask parts. Our carbon requirements were expanding at a rate that would have needed 400 tons of raw materials a day by December, 1918. We built 336,919 K–T masks and approximately 200,000 A–T masks.

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In exact figures, the total production of masks of all types was 5,692,499. Of these, 3,666,683 were built at the gas-defense plant and 2,025,816 were assembled by the Hero Manufacturing Company. In addition, we furnished 3,189,357 extra filled canisters for the replacement of those used up by forty hours of field service.

Simultaneously with this procurement and manufacturing achievement came the development of the technical section of the Gas Defense Division. This was known as the Long Island laboratories. It was manned by a *personnel* of several hundred men and officers. Here in its laboratories were solved the knotty problems that lay between experimental work and production. Many new designs were worked out, only to be rejected when tested. Here there were workrooms that could make sample lots of 1,000 masks, and here were located the chemical laboratories and the gas chambers in which the product of the gas-defense plant was tested daily by control chemical analysis and by actual breathing and wearing tests.

In spite of the elaborateness of this technical section, the testing of masks did not stop with it. There was a special field-testing section of the Gas Defense Division, composed of about 150 men trained to the minute in field maneuvers, who did most of their work in gas masks. They were constantly in and out of gas with regular production and experimental masks, they played baseball in them, they dug trenches, laid out wire, cut wire, and fought sham battles at night, both with and without actual gas. This section was not organized until July, but it should have been one of the first of our units. It was through it that we learned all the fine points of comfort and durability in gas masks. The work of this section even went so far in testing later designs as to include a test in which six men worked, played, and slept in the masks for an entire week, only taking them off for thirty minutes at each mealtime, and each day entering high concentrations of the most deadly gases, without any ill effects whatsoever to the wearers. When it is remembered that eight hours was the limit of time during

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which a strong man could wear the old-type mask, something of the efficiency of the new mask can be realized.

We also built 377,881 horse masks. Investigation showed that a horse's eyes did not shed tears in the presence of even strong lachrymatory gases. Moreover, a horse never breathes through his mouth; and it was, therefore, necessary to cover only his nostrils. Furthermore, the horse proved to be more resistant to the toxic gases used in Europe than men were, and his mask, accordingly, needed to be only a bag of many layers of chemically treated gauze. The horse masks were all manufactured by the Fifth Avenue Uniform Company, of New York City, under the supervision of a detachment of the Gas Defense Division.

We furnished 191,338 dugout blankets to be used at the doors of dugouts to make them gas proof. These were specially woven all-cotton blankets which were treated in France with a special heavy oil, shipped from the United States. Toward the end of the war we received large requisitions for protective suits and gloves to safeguard men against mustard-gas burns. The suits were made of oiled fabric and the gloves were of cloth impregnated with chemicals. As the preliminary output of a work barely started, we produced 2,450 suits and 1,773 pairs of gloves. A total of 1,246 tons of a new ointment known as sag paste was made and shipped. This was an ointment to protect the skin against mustard-gas burns.

Gas warning signals were of several types, watchmen's rattles and Klaxon horns being the most commonly used to sound the gas alarms. We shipped 45,906 of these special hand horns. The rattles were secured in Europe. Trench fans, for fanning out gas from trenches and dugouts, were produced to the number of 50,549.

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Gas-Defense Equipment

Item	Production: Up to July 1, 1918	Production: Up to Nov. 11, 1918	Total production	Shipped overseas: July 1, 1918	Shipped overseas: Nov. 11, 1918
Respirators	1,719,424	5,276,515	5,692,499	1,196,787	3,938,808
Extra canisters	507,663	3,144,485	3,189,357	484,236	1,805,076
Horse masks	154,094	366,529	377,881	101,250	351,270
Bleaching powder (tons)	1,484	3,677	3,677	586	1,867
Extra anti-dimming (tubes)	......	2,855,776	2,855,776	......	2,855,776
Sag paste (tons)	20	1,136	1,246	......	915
Dugout blanket oil (gallons)	......	95,000	95,000	......	5,000
Protective suits	......	500	2,450	......	......
Protective gloves	......	1,773	1,773	......	......
Dugout blankets	......	159,127	191,338	......	36,221
Warning devices	......	33,202	45,906	......	19,620
Trench fans	11,343	29,977	50,549	9,600	27,690

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CHAPTER XXVI

GENERAL ENGINEERING SUPPLIES

PRIMARILY a combat force, the Corps of Engineers conducted its most notable activities on the front itself, in the zone beaten by enemy fire. There the Engineers built roads and trestles for the American troops' advance across shell-torn ground, removed wire entanglements, and in general maintained the physical lines of communication for the infantry and artillery. In addition to this important duty, the Corps of Engineers was in charge of all military construction for the A. E. F., including the construction of the expedition's military railways.

In all, the Engineers in France handled some 3,300,000 tons of supplies, not quite half of which were received from the United States. In France the Engineers operated cement mills, contracted with French and English cement manufacturers, and produced the 215,000 tons of cement used by the A. E. F. To secure lumber for barracks, hospitals, storage depots, and the like, the Engineers felled the French forests at the rate, eventually, of 50,000,000 board feet of lumber a month. The Engineers developed the French port facilities granted to the A. E. F., and in connecting them with the zone of advance built 937 single-track miles of railway. In addition the Engineers constructed over 500 miles of narrow-gauge (60-centimeter) track and placed in operation thereon about 350 steam and gasoline locomotives and over 3,000 cars of various types. Most of the materials used in this heavy construction was produced in the United States and shipped abroad.

Of these supplies the materials used in railway construction were bulkiest and most important. One of General Pershing's first acts, on reaching France in the early summer of 1917,

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Military Engineering Supplies Shipped to the A. E. F.

Item	*Tons*
General machinery	45,454
Iron and steel products	242,226
Hardware and hand tools	26,780
Railway rolling stock	343,888
Railway motive power	144,066
Lumber	39,086
Track materials and fastenings	488,793
Automotive transportation, etc.	22,127
Horse-drawn transportation	7,967
Building materials and supplies	98,671
Liquids	7,067
Explosives and accessories	952
Unit accountability	7
Engineer supplies	52,106
Miscellaneous office supplies	2,239
Floating equipment and accessories	10,093
Material and tools for locomotive and car repair and erection shops	10,407
Total from United States	1,541,929

was to order great quantities of railroad materials, including fabricated narrow-gauge track that could be laid rapidly, even under fire. In cablegrams dated July 10 and 15, 1917, the commander of the A. E. F. requisitioned, among other things, 300 locomotives and 2,000 kilometers of standard-gauge track and large quantities of narrow-gauge locomotives, cars, and track.

HEAVY RAILWAY EQUIPMENT

Two American builders had been turning out locomotives for the military railways of the Allies—the American Locomotive Works and the Baldwin Locomotive Works. The American Locomotive Works had been making consolidation engines (the ordinary freight engines) for the French, and the Baldwins, locomotives of the same type for the British Expeditionary Force in France. Therefore the American Engineer Department turned to these two sources for A. E. F. standard-gauge

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engines, ordering 150 from each. The engine specified weighed 166,400 pounds, which, though not nearly so large or heavy as the freight engine generally used on American railroads, was about as big as could get within French platform and tunnel clearances. These engines had four drive wheels on each side and one pair of truck wheels.

The Baldwins received their order on July 19, 1917, and twenty working days later, on August 10, delivered the first engine, a record in swift locomotive construction. The company delivered all 150 before the end of October. The American Locomotive Works was nearly as expeditious, delivering the final engines on its contract in November. The American and Baldwin engines cost the Government, respectively, $49,600 and $44,940 apiece.

After this rush order had been filled, the Engineer Department, following the general tendency in military transportation equipment, set about standardizing A. E. F. locomotives in order to simplify the problems of operation, upkeep, and repair. After due consideration, the Baldwin product was adopted as the standard overseas broad-gauge locomotive, and in all over 3,300 engines were ordered from the Baldwin Company. The company delivered about 1,800 locomotives to the Government before the post-armistice termination of the contracts. The Government gradually scaled down the prices of engines, paying $37,000 apiece for them at the end and saving close to $23,000,000 of what they would have cost at the original price. Over 1,300 of these engines were shipped to the A. E. F., which had over 900 of them in service on the day of the armistice.

In exporting the engines the Government adopted the unheard-of practice of shipping them set up and on their own wheels, stacked bodily within the holds of vessels. It was the first time that locomotives had ever crossed the ocean in this fashion, and the manufacturers of the engines and some of our most practical shipping men advised against it. We took our cue from the British, who were shipping set-up locomotives across the Channel, at a great saving in money and time. The first

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thought was to run across the Atlantic big car ferries, like those that ply between Havana and Key West, but an examination of those available convinced the military shipping authorities that such vessels were unfit to encounter the heavy weather of the North Atlantic. Before our entrance into the war, one of the big eastern steel companies had contracted for a number of ships specially designed to carry iron ore from Cuba to the United States. When the United States Shipping Board commandeered the American shipping in commission and requisitioned all tonnage under construction, these ore vessels were nearing completion at the shipyards. The ore boats were built with unusually large hatches, through which the assembled locomotives could be lowered, and it was decided to use these ships for carrying the engines. There were four of these boats—the *Feltore*, the *Cubore*, the *Firmore*, and the *Santore*. The *Feltore* was the first to take a load of assembled locomotives across. She was loaded with thirty-three engines, packed in the hold and braced with baled hay so that they could not move. She sailed with her unique load on May 18, 1918, and her subsequent arrival in France brought from General Pershing a cablegram which read as follows:

> Shipment of erected locomotives transmitted on the *Feltore* very satisfactory. Boat completely discharged of locomotives and cargoes in 13 days with saving of 15 ship's days in unloading the 33 locomotives erected as compared with same number of locomotives not erected and further saving of 14 days of erecting forces. Observations of Capt. Byron, who came with these locomotives, show that by loading locomotives in double tiers, placing cab parts and tools, now in separate packages, within tender space and fire boxes, 40 to 45 locomotives can be loaded.

The export of engines on their own wheels was wasteful of ship space, but, as General Pershing indicated in his message, it saved nearly a month in getting an A. E. F. engine ready for road service. And time was the chief consideration then. One of the factors conditioning the movement of army supplies across the Atlantic was the ability of the A. E. F.'s railway equipment to move the stuff away after the cargo trans-

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ports had piled it up on the American docks in France. After the experiment with the *Feltore* all the broad-gauge locomotives were loaded on their wheels in ships, and 533 in all crossed the Atlantic in this way. The innovation saved about $1,500 a locomotive by doing away with the cost of crating the machine on this side and the cost of assembling it after it reached France. Formerly a locomotive had been crated in nineteen packages.

It was the intention, too, to export assembled freight cars, but the armistice came just as we were preparing to send 1,000 cars over in this manner.

The military locomotives, though built for service in France, came to the rescue of the American railroads during the severe winter of 1917-1918 and the consequent shortage in motive power. At that time the Baldwin Works was turning out locomotives faster than the ships could take them to France, so the railroad development of the A. E. F. could not be held back by the temporary use of these export engines on the domestic tracks. At different times the Engineer Department leased 142 consolidation locomotives to the United States Railroad Administration, and received a rental for them at the rate of 32.3 per cent of their cost per annum. Each locomotive worked an average of six months and twenty-eight days before being called in for shipment to the A. E. F.

When the Russian Government collapsed it left in the hands of the Baldwin and American Works 200 locomotives, built, but not delivered to Russia. The Director General of Military Railways bought these in at $55,000 each, changed their gauge and coupling system to meet our standards, and turned them over to the Railroad Administration. These engines earned over $2,500,000 for the War Department.

The Engineer Department procured and shipped to France over 18,000 freight cars, chiefly of the 60,000-pound size. By scaling down prices the Government saved about $16,000,000 in the purchase of this equipment. These cars would make a train 140 miles long.

At the end of the effort the Baldwin Company was turning

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out military locomotives at the rate of 300 a month, the greatest capacity ever attained by an American engine builder; and the production of freight cars was approaching the figure of 11,000 complete cars a month.

The first military purchase of steel rails amounted to 102,000 tons. The Government set the price at $38 a ton for Bessemer steel rails and $40 a ton for open-hearth steel rails, and invited the American steel companies to produce them for us at that rate. At that time the Russians were paying an average of $59 a ton for American steel rails and the French from $54 to $62. The Cambria Steel Company and the Bethlehem Steel Company declined to participate in the work at the war department prices, but the Lackawanna Steel Company and the United States Steel Products Company agreed to the figures and turned out the rails, at a saving to the Government of approximately $2,000,000.

These orders were placed pending the adjustment of steel prices by the War Industries Board. The Board stabilized the steel industry by fixing prices that would be alike for all purchasers—the Government itself, the Allies, and private industry. The prices fixed eventually for Bessemer-process and open-hearth steel rails were $55 and $57 a ton respectively, and all subsequent war department orders for rails were placed at those prices.

The Engineer Department saved immense sums of money in the procurement of freight cars for the overseas forces. The requisition from the A. E. F. called at the outset for 17,000 cars of French type. These were small cars, varying in capacity from ten to twenty tons, and built with only four wheels, two at each end. Our builders demurred, recommending instead a smaller number of larger cars designed on American lines. The car recommended would carry thirty tons, and it rode on four-wheel trucks, one at each end, exactly as the American freight car is built. The A. E. F. agreed to the change, and 6,000 American-type cars were substituted for the 17,000 French-type cars originally requisitioned. Thereafter we continued to build and ship cars of this type, saving about $190,000,000

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of what it would have cost to manufacture and ship French cars.

Under the fixed steel prices the Colorado Fuel & Iron Company and the Sweets Steel Company produced rails and bars, in addition to the four companies named above. The Standard Steel Car Company produced enormous quantities of metallic parts for the military freight cars. The American Locomotive Company, the Vulcan Company, the H. K. Porter Company, and the Davenport Locomotive Works built special types of standard-gauge locomotives for our tracks in France.

NARROW-GAUGE EQUIPMENT

The 60-centimeter trackage and equipment requisitioned by the A. E. F. were largely new to the manufacturers in the United States. The original requisition called for 195 narrow-gauge steam locomotives, 126 gasoline 40-H.P. locomotives, 63 gasoline 20-H.P. locomotives, and over 3,000 narrow-gauge cars, including 10-ton box and flat cars, tank cars, and dump cars. To show what was wanted, the A. E. F. sent back many drawings and photographs.

As in connection with the standard-gauge freight cars, our designers on this side of the ocean discouraged the use of the four-wheeled cars specified in the A. E. F. requisition and urged the substitution of four-wheel trucks, one truck at each end. The A. E. F. agreed to this recommendation. The narrow-gauge locomotives, both steam-driven and gasoline-powered, were built to run in either direction with equal facility, so as to do away with the necessity of building turntables or Y's. A gasoline engine of standard gauge had already been perfected and used to a limited extent in this country, and for our military gasoline locomotive we adapted this existing model to the 60-centimeter track. The Baldwin Locomotive Works built the first ones for the Government.

Deliveries of both locomotives and cars began in the autumn of 1917. Before the armistice we shipped overseas, of narrow-gauge equipment, 191 steam engines, 108 gasoline 50-H.P. engines, 62 gasoline 35-H.P. engines, 600 box cars, 500 flat

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Photo by Signal Corps

AMERICAN RATION TRAIN IN FRANCE

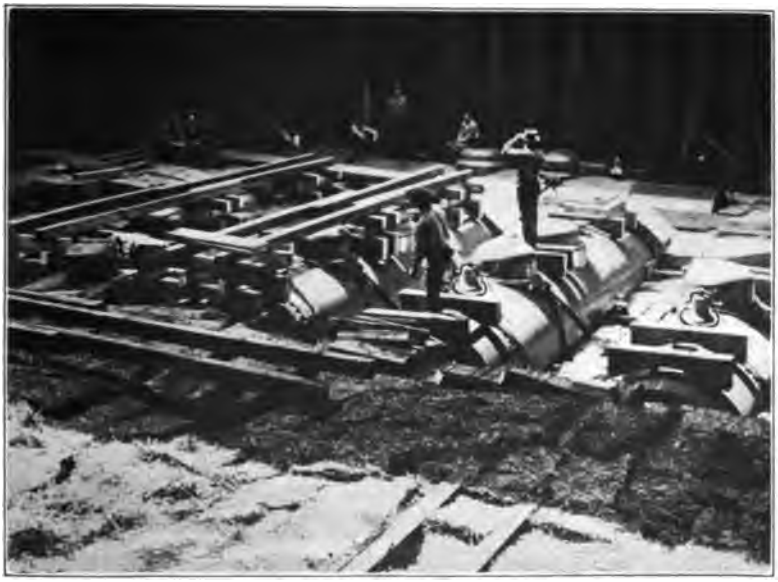

Photo from Engineer Department

LOCOMOTIVES ON WHEELS PACKED WITH BALED HAY
IN HOLD OF TRANSPORT

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Photo from Davenport Locomotive Works

NARROW-GAUGE STEAM LOCOMOTIVE SUPPLIED TO A. E. F.

Photo from Engineer Department

NARROW-GAUGE GASOLINE LOCOMOTIVE SUPPLIED TO A. E. F.

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cars, 1,555 gondolas, 166 tank cars, 330 dump cars, 100 artillery truck cars, 970 motor-driven cars, 180 inspection cars, 990 push cars, and 300 hand cars—361 locomotives and 5,691 cars in all.

For the construction of the narrow-gauge railroad used in the combat areas behind the front-line trenches, a special type of fabricated track was designed. This consisted of short sections of rail bolted to steel crossties. The American narrow-gauge railway was so arranged that it could be packed in knockdown shape to save shipping space. Most of this track was in 5-meter lengths, although many shorter sections were used. All, however, were in multiples of one and one-fourth meters, accurately sawed so as to ensure absolute fit of intermediate sections when shell fire made replacement necessary. Vast quantities of curved track, as well as innumerable switches and turnouts were also built. In all, about 605 miles of fabricated narrow-gauge steel track were purchased and 460 miles shipped to France. All but 192 miles of the fabricated track was built by the Lakewood Engineering Company, near Cleveland. The rest of it was obtained from the United States Steel Products Company. The cost of the straight track was about $7,400 a mile; that of the curved sections, $8,000 a mile. Much of this narrow-gauge track that went to France was manufactured at the rate of between five and six miles of completed track a day. Great quantities of the fabricated track produced by the Lakewood Engineering Company were loaded upon camouflaged steamers in Cleveland in May, 1918, and sent direct to France, *via* Lake Erie, the Welland Canal, and the St. Lawrence River.

OTHER ENGINEERING EQUIPMENT

A vast quantity of motorized or portable equipment was required by the engineer units of the American Expeditionary Forces, most of which had to be furnished under the supervision of the Engineers in this country. The extent to which this material was produced is shown by such items as 6,923 trucks of all kinds, 2,082 portable buildings, 124 portable

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shop and material trucks, 51 portable pile drivers, 90 electric storage trucks, 6,006 boilers, and 3,504 dump cars. Two-thirds of this equipment was shipped overseas before the armistice was signed.

The development of mobile shops was one of the most interesting phases of this branch of engineering work. Early in the war, when we began the construction of the great base shops in France, we developed these portable machine shops, blacksmith shops, carpenter shops, and storeroom shops in demountable truck bodies, to be used for general service in the field. The shops were so constructed that they could be entirely closed up when the unit was in motion; but when the shop was ready for use the sides and ends of the enclosing structure were lowered, forming worktables when the shop was left on the truck chassis. If the shop were entirely demounted, these sides and ends, let down, formed extensions of the floor. With this arrangement a wide variety of general repair and construction work could be handled on the spot on short notice. If it were necessary for the shop to stay in one place for several days or weeks, the body could be demounted, and the truck chassis was then used for transporting materials to and from the shop.

Each portable shop contained about 800 different items of tools and equipment. Each was mounted on a 5½-ton truck. The portable machine shop contained a workbench, a drill press, a portable electric drill, a grinder, and a 14-inch lathe, these being operated by an electric power plant carried on the truck; and it also had an equipment of necessary small tools and supplies, including an oxyacetylene welding outfit. The portable blacksmith, plumbing, and tin shops each contained a workbench, forges, hoists, pipe-fitting machines, a shear and punch, vises, and a welding and cutting outfit, together with a power plant and switchboard and the necessary small tools and supplies. The portable carpenter shop contained boring machines, a drill press, a bench grinder, a workbench, a saw bench, a winch, power plant and switchboard, small tools, and supplies.

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A complete machine shop on wheels cost the Government about $8,500. The carpenter shop cost $7,600. As supply units for the portable shops, the Government built thirty material trucks, each containing about 600 items of tools and supplies. These material trucks cost $6,100 apiece.

Another successful development of this sort was the portable photolithographic press truck, for use in making maps at the front. These automobile presses, which were at our front soon after our troops went into the trenches, were able to print and distribute lithographic sketches and maps within twelve hours after the original sketches were submitted for reproduction. The French and British armies also had mobile photolithographic units, but these were much less mobile than ours and much slower in operation. The best time made by the French and British outfits was four days for the same work.

We also supplied to the engineering forces abroad special water sterilizers and water tanks, mounted on trucks. The Engineers put small job-printing shops on trucks and photographic dark rooms on trucks for use in the field. They equipped trucks with derricks, capstans, and wrecking machinery. They furnished automotive road sprinklers and oilers, as well as trucks with special dump bodies for highway work. They developed a light, portable pile driver unlike anything used theretofore in commercial work. This machine was constructed of structural steel and had a total weight of four tons. It was mounted on a truck drawn by horses or mules, and the pile driver itself was operated by a 25-horsepower gasoline engine. The pile driver could be used within sixteen minutes after its arrival at any point.

One development of this sort, the mobile clam-shell derrick, is worth noting. This unique piece of machinery was built by the Winther Motor Truck Company, of Kenosha, Wisconsin. When the American Expeditionary Forces issued a requisition for 120 clam-shell derricks mounted on motor trucks, no such piece of equipment was in existence anywhere on earth. The Winther Company volunteered to attempt to produce the machine. By giving a wider tread to the rear wheels of the

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Winther motor truck, the company could provide a suitable vehicle, but, search as they might, they could not find a derrick of sufficient power to operate a half-yard clam shell and also light enough to mount on a seven-ton truck. No such derrick existed. The company, therefore, without knowing anything about the manufacture of derricks, put its engineering force to work to produce a design. This design was developed in two weeks, and the derrick built from it was less than half the weight of any derrick of equal capacity. After being perfected, the mobile derrick showed in tests that it could move 350 cubic yards of sand or gravel a day, or from 500 to 600 tons of coal. One man could operate it, and the motive power was a 4-cylinder gasoline engine. The Engineering Department approved this design and ordered thirty-two such clam-shell units. Nine of these were delivered before the armistice was signed. The company continued production of these derricks with a view of selling them commercially.

For use of the various engineer units we manufactured 1,610 tool wagons and shipped most of them to France. Because of the rough nature of the shell-torn ground over which these wagons must be used, we designed each to be uncoupled and operated as two two-wheeled carts.

The development of mobile industrial units mounted on motor trucks is likely to have a profound effect on American industry in the future. For instance, the special derrick or crane trucks which we built are almost certain to be adopted in commercial use. The locomotive crane has always been a useful machine, but its chief use has been in handling heavy materials which were being loaded on or off railway cars. A crane which can be moved rapidly to places where railway tracks are not located should be of almost equal importance. In the same way the mobile pile drivers designed by the Engineer Corps should be of great future service in road building in this country. The various machine shops which were built for war purposes will, in their duplications and adaptations, undoubtedly serve a useful purpose in future commercial activities in this country. The increased use of motive

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power on farms has created a demand for machine repairs. The day may come when the traveling machine shop will be a familiar sight on our rural highways.

The Engineer troops required a great quantity of hoisting machinery. Our purchases in this respect amounted to 700 cranes, mostly of the locomotive type, and 886 hoisting engines, at a total cost of $4,996,000. About two-thirds of this equipment was sent to France and installed at the ports of debarkation and at supply depots. The rest was used at the shipping points in this country. This machinery was of great aid in the rapid handling of materials at tidewater.

A vast amount of small tools and construction material was required.

Some 21,000 tons of barbed wire, shipped abroad to be used principally in the construction of entanglements in front of American battle positions, were manufactured principally by the United States Steel Products Company, Jones & Laughlin, the Gulf States Steel Company, and the Colorado Fuel & Iron Company, although several other firms also supplied barbed wire.

The Engineering Department ordered in the United States, during the fighting, equipment and supplies which cost approximately $754,201,407.

We furnished, in all, 85,120 steel shelters of various sizes, of which 38,320 were of the individual type which could be carried by one man. The steel used in these individual shelters was about one-eighth of an inch thick.

There may be expected to be great incidental benefit to future American industry from improvements and inventions brought out by American military engineering in 1917 and 1918. One important work, for instance, which the Engineer Department undertook was standardizing the requirements for paints and varnishes. At the outset our army needs ran into twenty-nine shades of color in 315 different paint and varnish mixtures. Without affecting any of our camouflage projects or other important undertakings, we reduced the number of shades required to sixteen and brought the total number of

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commodities down from 315 to 99. This reduction in the range of commodities will be of great use to the paint and varnish industry in the future.

At the beginning of the war the mechanical rubber industry had but few standard specifications. The Engineers, after considerable research, developed thirty standard specifications for mechanical rubber goods, which class included such materials as hose, packing, and sleeves. The representatives of the rubber industry stated orally that the Engineer Department, in this short time, did more good to the trade than it had been able to accomplish for itself in the previous three or four years of effort. Immediately after hostilities stopped, rubber concerns began asking the Engineer Department for its standard specifications.

In the manufacture of hardware and kitchen utensils there was also considerable standardization done, and changes in manufacturing methods were recommended which were put into effect by the producers. All spun goods were eliminated, and the industry confined itself to straight stamping, which meant a reduction in labor. A standard cobalt coating for enamel ware was developed by which the industry conserved about thirty tons of niter a month and made a more durable and satisfactory enamel coating, with the result that to-day the Army is purchasing its vast quantities of enamel ware subject to certain tests, whereas, in the past, practically all this material was bought purely upon the manufacturers' statements. The shortage of tin was of considerable importance. Upon the recommendation of an engineer officer enormous quantities of cafeteria trays were coated with zinc and large amounts of tin thereby conserved. The finished tray was entirely satisfactory and gave essentially the same service as that plated with tin. Horseshoe nails, formerly a variable product, were standardized and tested, and methods were devised by which the Army was enabled to control their quality.

Before the war there was no standard rating for internal-combustion engines, each manufacturer rating his motors according to his own ideas. Our studies of small engines of the

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type used for driving pumps or operating woodworking and metal-working machines resulted in many improvements, which have been adopted by the manufacturers of internal-combustion engines. Out of these studies came the so-called army rating, a standard which is bound to result in the more careful rating of commercial engines.

The Engineer Department brought out a modification of the design of the existing line of gasoline-driven shovels by applying caterpillar traction to the larger sizes, thus doing away with the labor required to plank up and block shovels that move on wheels.

When we entered the war, the explosive trinitrotoluol was standard for our Army for mining and demolition purposes. The Bureau of Mines, in coöperation with the Engineer Department, developed an explosive which is cheaper than T. N. T. and promises to replace it for engineering operations. We also improved the devices commercially used in the electrical detonation of distributed charges, our improved detonators being more certain and reliable than anything in use. Commercial machines for detonating as many as 250 standard No. 8 caps were developed for the Panama Canal, but the machines in common use had seen little improvement for twenty-five years. As a result of the development by the Engineer Corps, a machine capable of detonating 120 caps was obtained, which weighed no more than the 30-cap commercial blasting machine and cost slightly less. A second machine was developed, capable of exploding 500 caps, at a price not greatly above the price of a 30-cap commercial machine. Mining engineers who saw this development stated that it would have a high commercial value, as these improved machines would make electric blasting more positive and dependable than any other form of detonation, as well as making it possible to set off a large series of charges simultaneously. The Panama Canal machine weighed thirty-five pounds and cost $126. Our 500-cap machine weighed thirty pounds and cost $35. The DuPont 30-cap machine weighed twenty-five pounds and cost $25. Our

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small machine weighed twenty pounds, cost $22.50, and would fire 120 caps.

There might be mentioned other projects developed primarily for war purposes, but available for the industrial uses of peace. These included portable well-drilling outfits of a new type, alcohol stills of a small size for the utilization of waste products in small units, sound reducers on the exhaust pipes of gasoline engines, and air strainers to minimize the chances of dust and grit entering gasoline engines. When the war ended we were working on the problem of hastening the setting of concrete and were also studying the production in this country of photographic colors and tone chemicals formerly secured only from Germany.

In general, mention should be made of the exhaustive tests in many industries conducted by the Engineer Depot and by special detachments of Engineers. Tests were made of hundreds of pieces of apparatus, and these tests led to many improvements in American manufacture. Here is one illustration of how these tests were regarded by individual concerns. The Cleveland Tractor Company, after a test of its equipment conducted by army engineers, stated: "Our people consider this test to be the most valuable ever undertaken by this company." This is indicative of benefits scattered throughout American industry by the engineering war tests.

Practically all the research work which resulted in the developments and improvements noted was conducted by engineer officers while on duty at the General Engineer Depot in Washington. For handling engineer materials there were established, besides the General Engineer Depot at Washington, D. C., embarkation depots at South Kearney, New Jersey, and Norfolk, Virginia, and shipping depots at Baltimore, Philadelphia, Jacksonville, New Orleans, and Mobile. In addition, sub-depots were organized at all the divisional camps and cantonments.

The war demanded the production in America of quantities of instruments of precision. These were required not only by the Ordnance Department for the equipment of artillery with

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sights and indirect fire-control apparatus, but also by the Engineer Corps, the Signal Corps, the Bureau of Aircraft Production, and the Medical Department. These instruments were such things as aneroid barometers, pocket compasses, measuring tapes, surveyors' equipment generally, map-drawing outfits, draftsmen's supplies, and so on. For a large period of the war the procurement of instruments of precision was in the hands of the General Engineer Depot. Later, when the War Department's supply activities were being consolidated, the purchasing of such instruments, except the highly technical sound-ranging devices, was taken over by the Director of Purchase, Storage, and Traffic, the organization of the General Engineer Depot going along in the transfer. The development and the production of searchlights and sound-ranging apparatus remained in the hands of the Engineer Corps.

In April, 1917, there were probably not more than a dozen recognized American manufacturers of high-grade instruments of precision. As an indication of the expansion of manufacturing capacity required by the war, one concern, the Taylor Instrument Companies, of Rochester, New York, which had manufactured in peace times watch-pocket compasses at the rate of 15,000 a year, were called upon to turn them out at the rate of 10,000 weekly to fill an order for 200,000. In order to handle this contract the Taylor Instrument Companies put up a new factory building in twenty days. A certain type of aneroid barometer required by the exigencies had never before been produced in America. The Taylor Instrument Companies succeeded in producing 1,240 of these barometers.

The Lufkin Rule Company, of Saginaw, Michigan, was called upon to manufacture 700 band chain measuring tapes for surveying, graduated throughout according to the metric system, and also 1,240 special outfits for repairing such tape. These band tapes, when broken, are fastened together by tiny rivets, which are produced by special machinery. Because of the inability of the machine-tool industry, swamped as it was with war demands, to produce the special rivet-making machines, it was necessary in the specifications for repair outfits

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to reduce the quantity of metal rivets for each kit from four ounces of rivets to two ounces.

Field artillery required an instrument of precision known as the miniature telescopic alidade of the Gale type. It is unlikely that 150 of these instruments had been made in the United States during ten years. The artillery demands called for 1,110 of them. The W. & L. E. Gurley Company, of Troy, New York, not only manufactured half this order, but, in order that the Government might obtain a sufficient supply of the instruments, turned over to a competing firm, the Eugene Dietzgen Company, of Chicago, the lenses, prisms, hermetically sealed bubbles, and other parts for 555 instruments.

The Army required large numbers of hand tally registers, to be used by checkers and observers. The Benton Manufacturing Company, of New York, which had been making less than 15,000 registers of this sort in a year, increased its facilities and turned out 62,000 of them for the Army within two months.

The Army required 35,000 complete sketching outfits for the use of military observers. The contents of these outfits were manufactured by a dozen different concerns.

Drawing instrument sets were produced by the Eugene Dietzgen Company. Each set included a pair of proportional dividers. Our draftsmen had always obtained their dividers from Europe. The divider, which nearly everyone has seen, appears to be a simple device; yet it must be made with the utmost precision, or it is valueless. In manufacture it goes through more than a hundred distinct factory operations.

Marching compasses for troops were made by the Sperry Gyroscope Company, of Brooklyn, New York, the quantity in manufacture being over 200,000 instruments.

Many other delicate instruments of most difficult manufacture, the description of which is too technical to be set down here, were produced successfully in America during the war period.

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Photo from Engineer Department

ARMY MOBILE MACHINE SHOP

Photo from Engineer Department

ARMORED CAR WITH GUN AND SEARCHLIGHT

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SURFACE SOUND-RANGING SET

GEOPHONE

Photos from Engineer Department

MICROPHONE

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CHAPTER XXVII

LISTENING GEAR AND SEARCHLIGHTS

IN childhood we were enthralled by the tales of those magic persons whose keen hearing could detect even the whisper of the growing grass. As camouflage developed, modern warfare yearned for such supernatural gifts of sense, that troops might detect the unseen presence of the enemy. Accordingly Science, the fairy godmother of to-day's soldiers, raised her wand, and lo, the Army was equipped with the wonderful ears of the fairy tale, uncanny no longer, but a concrete manufacturing proposition.

Artillery practice nowadays abhors the wasted shot. The time when cannon fired in the general direction of the enemy and hoped to hit something passed when the long-range rifles and howitzers, with their marvelously accurate sighting instruments, came into existence. Whole books have been written on the subject of pointing a modern cannon in the modern way. A great proportion of our industrial effort in the recent conflict was devoted to the sole end that we might aim our artillery accurately.

For instance, to this end almost exclusively was devoted the enormous production of aircraft material. The observer in the airplane or balloon trusted, not to his eyes, but to the finer sight of the photographic camera; and this again occasioned a large war industry—the production of cameras and their operation in the field, which included the production of finished photography in the field dark rooms. But, as the airplane and the aërial camera were perfected, camouflage was undertaken as a protection from discovery from aloft; and so might be brought in another chapter—the production of camouflage material and the work of camouflage experts in the field. Pres-

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ently camouflage succeeded in baffling the camera to a great extent, and this made necessary the development of instruments that could detect the location of the enemy by sound. Since the unaided ear was not keen enough to supply the desired information, applied science came to the rescue with the various devices embraced in the general classification of sound-ranging equipment. The production of this equipment was under the direction of the Engineer Department of the Army.

In three classes of military work we needed hearing refined to the razor edge. With keen enough ears we could detect those subterranean operations of the enemy known as mining; with ears of that sort we could detect and locate the positions of hostile cannon; and still again we could employ such sensitiveness of hearing to find, in the darkest night sky, the hostile raiding airplane.

One of these long-distance ear drums which man invented for himself as an aid to his military operations was known as the geophone. The first geophone used by the western powers in the war was invented by the French. It was a simple mechanism. The device or drum which received the sound waves and magnified them consisted of a small closed box with a confined air space. This box was weighted with a leaden disk to give it the required inertia. The geophone was placed upon the ground and the vibrations of the earth were communicated through the medium of the confined air space. The sounds then reached the listener's ears by way of a rubber tube and an ordinary stethoscope horn. By this device the slightest vibrations of the ground were rendered audible.

The geophone was used to detect enemy mining operations. The listener placed the weighted box on the floor of an underground gallery or on solid earth or rock. If the enemy were burrowing in the ground anywhere within a distance of seventy-five yards, the geophone would tell about it. In order to enable the listener to know in what directions the sounds came, two geophone boxes were provided, one connected with each ear. By placing the boxes a small distance apart from each other and moving them until the vibrations in both ear horns

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were equalized, the listener could tell approximately in what direction the enemy mining operation was located. Geophones were used by both sides, and so effective did they prove to be that they are credited with having been largely instrumental in stopping mining operations altogether. If an enemy mine were located by one of these devices, a counter mine could be started at once and carried through, usually with disastrous results to the hostile miners.

As our first step in the production of geophones, we adopted the French device; but later on we developed an instrument with nearly one-third greater range than the French geophone had. This improvement was developed by the Engineers and specialists at the Bureau of Standards in Washington, with money provided by the Engineer Department. We produced the improved model in sufficient quantities to meet the requirements of the American Expeditionary Forces.

We also developed an electromechanical geophone that could be connected by wire to a central listening station some distance back from an exposed location. The sound-receiving boxes, or microphones, were placed out in No Man's Land and hidden under trash or earth. They were so sensitive that they would not only record any subterranean activities of the enemy within their range, but at night would betray enemy raiding parties attempting to cross to our positions, the sensitive boxes picking up the vibrations of their speech or footsteps. The central listener could locate approximately the position of hostile operations by observing which boxes were receiving the sounds in greatest intensity. The boxes could also pick up and send to the central listening stations conversations carried on by the enemy parties even in low tones, the apparatus thus acting as the dictaphone of the war.

But by far the most important work done by listening instruments was in locating the positions of enemy gun batteries. The apparatus which did this was one scientific instrument, at any rate, which the Germans were never able to produce successfully for themselves. During the final months of the war more enemy guns were located by listening instruments than

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by any other means. An American instrument with the Army spotted 117 German gun positions in a single day by surface sound ranging. This was the high American record set in the war, but at all times our sound-detecting equipment had an uncanny accuracy. Up to the end of the fighting, no way had been discovered to conceal the location of a gun from sound-ranging instruments suitably placed and properly operated.

The instruments used for locating gun positions were so highly complicated and technical that no one but designers and mechanics skilled in the production of complex electrical equipment could build them at all. The recording instruments, or microphones, were so delicate that their use theretofore had never been considered outside laboratories. Yet they were required to operate successfully amid the din and concussion of heavy bombardments. All useless sounds and jars were filtered out, so that only the sought-for vibrations could come to the central recording mechanism. Studies of gunfire showed that when a cannon fires an explosive shell of high velocity there are three distinct concussions. One of these is the sharp crack produced in the air when the shell, dragging a short vacuum trail behind it, passes over the head of the observer. As the air rushes into this vacuum and collides with itself, it produces a crack similar in origin to ordinary thunder. The second concussion to be heard is that produced at the muzzle of the gun by the expanding gases that propel the shell. There is still a third, the break or explosion. In order to locate a battery or gun exactly, only one of these concussions—the explosion at the muzzle of the gun—must be picked up by the microphone. The first and third shocks, and all other sounds not useful to the work, should be damped out and excluded.

A number of these microphones would be placed in scattered positions, usually in a trench, and then connected with the central recording mechanism. When a microphone picked up a hostile gun explosion the disturbance was instantly transmitted through several miles of wire. An ingenious and complicated mechanism actuated an electromagnetic needle, which instantly recorded this disturbance on a tape of photographic

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paper, calibrated to show fifths of seconds. Each microphone on outpost duty was represented on this tape by one of several parallel lines; and, as six microphones were usually used, the tape was striped with six parallel lines. As the other microphones at the front successively picked up the concussion of the gun, their records were made on their respective lines; and the observers at the central station, by noting the differences in time between the reports of the various microphones, and by making calculations based on the rate at which sound travels, could by means of ordinary surveyor's triangulations locate the gun that set up the disturbances. So accurately would this mechanism do the work that a gun position could be determined within fifty or sixty feet.

Incidentally, it is interesting to note that the practice of our Army was to secure in advance, by means of surface sound ranging and other methods, the positions of all the enemy's guns that could be learned. Then, often after intervals of hours or even days, the fire began simultaneously upon all these gun positions just as our attack started.

In this country we had two experimental stations for the development of sound-ranging apparatus. We began experiments in this work in June, 1917. Before we had perfected any satisfactory instruments, the British had met with great success with the Bull-Tucker system; and we adopted that type for the use of the American Expeditionary Forces. From plans and models sent to this country we produced an American Bull-Tucker machine, utilizing standard American electrical equipment wherever we could. At the close of the war we had in operation along the American front twelve completely American outfits. The six microphones of each recording machine in action were set about 5,000 feet apart along the front, so that each sound-ranging section covered a frontage of approximately five miles. The twelve outfits in use were sufficient to locate the guns of the enemy on a sixty-mile front.

About a month before the fighting stopped we sent to France a new model sound-ranging set which had been developed with the coöperation of the Bureau of Standards. The reports from

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the American Expeditionary Forces indicated that this American development was superior in several important particulars to anything else in use when the war came to an end. The American instruments were lighter, easier to carry about, easier to install, and much cheaper than those of the British type, and they would operate under more adverse weather conditions. The impulses received by the microphone in this equipment were recorded on a running tape smoked by an acetylene flame.

Sound ranging for the detection of airplanes at night required an equipment which consisted fundamentally of a sound-gathering device and a listening mechanism, the combination enabling the observer to tell the direction from which the sound was coming. When a bombing plane approached at night the hum of the motor could be heard at a distance of from one to three miles, or even more, according to conditions. But the direction of this sound was elusive to the unaided ear, as anyone can testify who has heard an airplane in broad daylight, but who could not locate it with his eyes. Before the invention of aërial sound ranging, the searchlights hunting for the hostile airplane were obliged to sweep the sky aimlessly in an endeavor to locate it; and the pilot of the plane could often maneuver to keep out of the light beams. But by the use of the sound detectors, not only could the approach of the airplane be detected at a distance beyond the hearing range of the unaided ear, but, what is more important, its direction could be determined within an angle of 3 degrees. The use of these sound detectors greatly increased the chances of locating airplanes at night by searchlight.

The Engineer Department conducted extensive experiments in the development of aërial sound detectors. One form developed consisted of a set of long horns with listening tubes attached to the small ends and leading to receivers on the observer's head set. These horns were mounted on a turntable which the observer could revolve, so that the horns could be turned in the general direction of the sound. Four horns were used in this mechanism—two to indicate the direction of the

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airplane on a horizontal circle (in azimuth), and the other pair to indicate the direction on the vertical arc (in elevation). Under favorable conditions the sensitiveness of this device was three times that of the unaided ear, and the airplane could be located within an angle of 1 degree. The horn detector, however, was large and cumbersome and not satisfactory for a mobile unit.

For field sound ranging in such conditions that the listener might wish to move from place to place, the parabloid sound reflector was developed. This hemispherical object, like a huge fountain basin in shape, was made of material similar to building board and shaped in parabolic lines. Such a sound collector echoed or reflected the sound from every point of its surface to a focal point where the listening instrument was located. The observer turned the parabloid on its universal mount until the sound was equalized in his ears, and then the exact direction of the airplane would be indicated by the azimuth and elevation pointers on the machine. The parabloids developed by our Engineer Department had a sensitiveness three times that of the unaided ear and could locate sound within 3 degrees of arc. We were not pioneers in developing the parabloid, for the French built them ahead of us; but our apparatus possessed marked advantages over that of the French. In the first place, the French collecting device weighed three and one-half tons and was so heavy and cumbersome that it could scarcely be moved at all. The total weight of the American collecting device was only 1,300 pounds. The American instrument was not only much lighter and more easily portable, but it was also so simple that it could be set up in about one-sixth the time that it took to erect the French device. The cost of our machine was only about two-fifths that of the French mechanism.

Although valuable work in detecting gun positions was done by sound ranging, both sides located guns by watching their flashes. We improved the flash-ranging sets of the Allies. These were simple in principle. A number of observers at posts commanding good views were equipped with observation telescopes mounted on tripods to watch for the flashes of enemy guns.

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Whenever two or more of them observed the same flash and reported its direction, the position of the gun could be determined by ordinary triangulation.

In actual operation the system was not so simple, however, because the reporting observers might not have turned their instruments upon the same flash. This difficulty was met by furnishing each observer with an outpost switch set. As soon as he observed the flash through his telescope he closed the switch, and that action turned on a small electric light at the headquarters station, which might be miles away. Then, as soon as he could, he telephoned the direction of the flash observed. If the operator at the switchboard saw two or three of the lights flash simultaneously, he knew the observers at the front had probably caught the same flash. Lights that came on a little ahead or a little behind the simultaneous lights were disregarded when the observers telephoned reports.

In developing the telescope for this system, considerable difficulty was experienced on account of the shortage of the proper optical glass in this country. We were therefore obliged to buy our telescopes in France until our supply should become available. These telescopes were expensive mechanisms, and in some of the work of the flash-ranging sections two of them were originally required at each observing station—one to determine the position of a flash in elevation and the other its position on the horizontal circle in azimuth. After the declaration of the armistice an American engineer officer designed a telescopic eyepiece which enabled this work to be done by observing through a single instrument, thus effecting a marked saving in the number of telescopes which may be required in the future.

When the fighting stopped, our military scientists and others coöperating with them were developing a type of ground sound-ranging apparatus which, it was hoped, could be utilized to give troops warning of the firing of heavy artillery shell in their general direction. Preliminary experiments showed that at a distance of 4.1 miles this mechanism could record the firing of a gun some nineteen seconds before the arrival of the shell.

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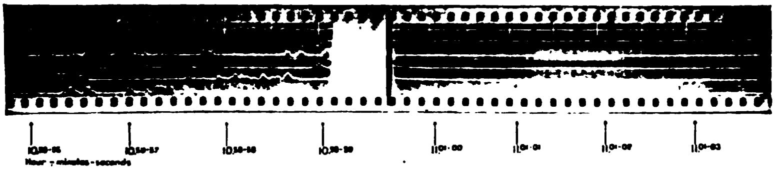

Photo from Engineer Department

"THE END OF THE WAR"

Reproduction of tape of American surface sound-ranging machine as operated between 10:58:56 and 11:01:03 a.m. on November 11, 1918, with two minutes cut out to show contrast. Broken lines before minute of armistice show intense artillery activity, all guns firing. Unbroken lines afterwards denote silence on front. Explosion breaks in second line from top probably caused by excited doughboy running out into No Man's Land and firing pistol in celebration near hidden microphone.

Photo from Engineer Department

AMERICAN PARABLOID

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Photo from Engineer Department

60-INCH PORTABLE OPEN-TYPE SEARCHLIGHT

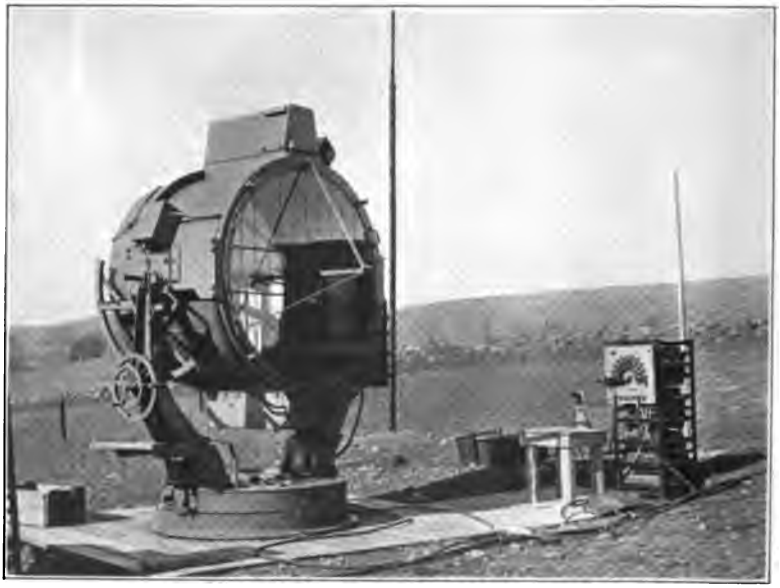

Photo from Engineer Department

60-INCH SEACOAST-TYPE SEARCHLIGHT

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Under proper circumstances this elapsed time would enable troops properly warned to seek cover from the explosion of the projectile. This development of sound-ranging apparatus and its application to the protection of *personnel* were made possible by the far greater speed with which shock vibrations travel through a dense medium like the earth than through the usual sound-conveying medium, the atmosphere.

SEARCHLIGHTS

THE searchlight equipment of the United States Army up to 1914 consisted chiefly of lights located at our coast defenses. In 1916 we began the development of mobile searchlight-and-power units for field-army work, four horse-drawn equipments, with 36-inch lights, being ordered first, and later eight other sets, with extensible towers and gasoline-electric generators. When the war was approaching we ordered eighty-five sets of the limber-and-caisson type. The caissons of these sets carried 24-inch lights on extensible towers. In January, 1917, we ordered fifty high-intensity lights to replace as many low-intensity lamps at our seacoast fortifications. The first war order was placed in April, 1917. It consisted of twenty additional searchlights of the 60-inch dimension, the largest light produced by the War Department. After the entrance of America into the war the Engineer Department began studying the requirements abroad for searchlights used in defense against hostile aircraft; and in September, 1917, this investigation resulted in orders for 360 high-intensity searchlights, 693 high-intensity arc mechanisms, and 1,000 glass mirrors of standard design.

About this time we began looking to the improvement of existing searchlight equipment, the coöperation of leading scientists, manufacturers, and government bureaus was obtained, and the product of exhaustive experiments was eighteen different new kinds of searchlights, either partially or wholly developed. The first of these were produced, shipped, and were in operation with the Second Field Army in France on October 1, 1918. This was a new form of searchlight, more powerful

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than any that had been produced before that time. It weighed one-eighth as much as lights of former design, cost only one-third as much, was about one-fourth as large in bulk, and threw a light 10 per cent stronger than any other portable projector in existence.

Without going into the details of this mechanism, we may note that its most striking innovation, from the standpoint of the nontechnical observer, was the absence of the front glass through which the beams of the older type of lamps are sent. The absence of the glass, while reducing the weight and cost of a light, also increased the intensity of the beam, since any glass, no matter how conducive to rays, absorbs considerable light.

In the first part of the war we took the 36-inch lights which the Government had on hand and mounted them on motor trucks. For generating power for the lights, motor trucks were equipped with electric generators operated by the crankshafts of the truck engines. In moving about, each truck carried not only the light and power unit and accessories, but also provided space for the crew and their equipment.

When we went into the war there was only one firm in the United States that could make the large searchlight mirrors, but two other concerns developed the art and the facilities during the hostilities. These mirrors were of glass and cost, at prewar prices, about $1,000. The maximum output in the United States before the war was three 60-inch mirrors a week. As the result of governmental encouragement, the production of the 60-inch mirrors increased until it reached the stage of fifteen a week in November, 1918; and the price was reduced to about $900 a mirror, even under wartime conditions of labor and material. This was equivalent to a price of about $700 a mirror under normal conditions, or a saving of 30 per cent.

A remarkable contribution of the United States to searchlight science was the production of a satisfactory metal mirror for projecting the beam. The metal mirror not only weighed a little less than the glass mirror, but it cost only one-third as

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much as the glass one, could be produced in one-fifth the time, was much less fragile, and extended the possibility of manufacture to a wide number of industries. The metal mirror possessed 97 per cent of the reflectivity of the glass mirror. This slight dullness is inappreciable in searchlight work and is more than compensated for by the other qualities of the metal reflector. This type of mirror, however, had not yet been put in production when the war ended.

Our inventors succeeded, during the nineteen months of hostilities, in reducing the size of carbons used in 200-ampere lamps from two inches in diameter to one and one-eighth inches. This cut the cost of carbons in two, and the improvements tripled the amount of light developed.

In November, 1918, we were working, with assurance of success, to develop a simple system whereby field searchlights could be pointed and controlled from a distance. Such controls had been used in experimental work prior to 1917, but the mechanisms were complicated and not suitable for field service.

The searchlight section of the Corps of Engineers also developed optical finding devices which doubled the range of all searchlights without any modification of the lights themselves. Neither the ordinary telescope nor the ordinary night glass is suitable for target finding by searchlight. The result of our investigation was the development of a combined observer's chair, eye protector, and searchlight target finder, the new equipment adding only 10 per cent to the cost of the searchlight unit.

The range of our modern high-power searchlight when its target was a ship at sea was about 15,000 yards; the range of the same searchlight when its target was an airplane was about 15,000 feet.

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CHAPTER XXVIII

SIGNAL MATERIAL

THE spent runner who, in the year 490 B. C., hurled himself through the gate of ancient Athens and with his dying breath gasped out the news of the brilliant success of the Athenian troops against the Persian at Marathon, was the first famous soldier of a signal corps; but since then the exploits of the bearers of military tidings have filled the pages of legend and story. Just as other branches of military science have been brought to a high perfection in modern times, so in equal degree has the art of military signaling progressed in efficiency. But where the ancient athlete once exhausted his strength in bearing military messages long distances in the field, the modern Mercury uses the wireless telephone. In Civil War days the pony express rider brought from some desperate stand the story of the lack of ammunition; to-day the ammunition-supply organization is in constant touch with the front by means of the telegraph or the long-distance telephone. In the Indian campaigns in our own West, messages from beleaguered parties were sometimes conveyed by signal smokes; the "lost battalion" in the Argonne sent news of its plight by carrier pigeon.

Modern warfare has indeed retained the old, but it has also developed the new, in transmitting military tidings. So important is this branch of fighting that it is put into the hands of a specialized organization, which in the American Army is known as the Signal Corps. The Signal Corps not only had charge of the operation of the various communicating devices in 1917 and 1918 in the field of operations (except, latterly, in the air), but it also had charge of the manufacture of the equipment for this work.

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The production of signaling equipment was far greater than the uninformed person would imagine. As an instance, there was one special type of telephone wire, a form unknown to commercial use before the war, which, before November 11, 1918, was being produced at the rate of 20,000 miles a month, at a cost of $5,650,000 a month, and which required the complete night-and-day capacity operation of all fine-wire machinery in the United States except that which was working on navy contracts. Many other production activities of the Signal Corps were carried through on a similar scale.

Until after the Civil War, the operation of large units of troops was greatly handicapped by the limitations of military signaling as then known. A force could not be effective in combat that could not be readily reached in all quarters by runners or riders or by visual signals. The development of the telegraph and telephone and the invention of radio communication so changed all this that in the World War armies, stretched out on fronts a hundred miles or more in length, kept every part in immediate touch with every other, through the exact and complete systems of signaling on the field. Military signals to-day include the telephone, the telegraph, radio telegraphy and telephony, the buzzer, the buzzerphone, panels, pyrotechnics, flags, smoke signals, pigeons, dogs, mounted orderlies, and runners. Each of these means of signaling is an adjunct to the others; when one fails, another is employed to get the message through. Some have special uses for branches of the service with peculiar requirements. The radiophone is especially suited for communicating from airplanes. Artillery fire is directed by wire and wireless communication. Trained pigeons are sometimes able to get messages through when all other means of communication have failed.

The Army did not have a great quantity of signaling equipment when it went to war with Germany, but what it did have was good. The American punitive expedition into Mexico, where long lines of communication over rugged country were required, had given opportunity for testing modern signal

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apparatus in the field. Many of the signaling devices used by the American Expeditionary Forces were, at least in type, in common use by the civilian population; but the procurement of this equipment offered heavy difficulties. This was because, as to the quality of material used, the Army was much more exacting than commercial demand was. For instance, a telephone instrument for use in the field can hardly be compared with the telephone in a business man's private office. The field set demands stronger connections, better insulation against the dampness of outdoor work, and more rugged construction to withstand rough usage by an army on the march.

One of the larger tasks of the Signal Corps in France was to provide communication facilities for the Services of Supply. The first signal corps officers sent to France soon realized that the forthcoming American Army could not depend upon the French telegraph and telephone systems in the various zones of operation, because those systems were already overburdened by the uses of the French Government. It was necessary for us to set up our own telegraph and telephone systems, extending them from the ports of debarkation through the various bases and zones up to the battle regions. The magnitude of the system which was finally constructed is shown by the fact that on November 11, the date of the armistice, there were in France 96,000 miles of American telegraph and long-distance telephone circuits. This wire was all used by the Services of Supply and by the various army bases behind the front. In the field of fighting the requirements for wire were even greater. At one time during the height of the operations it was evident that the time was not far distant when the Signal Corps would need 68,000 miles a month of what was known as outpost wire, for use simply in connecting up the telephone and telegraph systems carried along by the troops in their advances.

Outpost wire was entirely a development of the war against Germany. The original telephone system used at the front had been the single telephone wire, grounded to complete the circuit. But all the armies in France perfected their listening instruments to such a degree that they could hear conversations

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conducted on the grounded telephone circuits, the sounds being detected in the earth itself. Therefore it became necessary to carry forward with troops two-wire telephone circuits, thus doing away with ground connections. Even then, care had to be taken that the insulation of this double wire was perfect, lest the impulses enter the ground through gaps in the insulation. Wireless for outpost communication was equally impracticable, since the enemy could easily listen in and hear radio messages. Outpost wire ensured secret communication at the front. It was a twist of two wires, each single wire being made up of seven fine wires, four of bronze and three of hard carbon steel. These were stranded together, coated first with rubber and then with cotton yarn, and finally paraffined. The wire was produced in six colors—red, yellow, green, brown, black, and gray—for easy identification in the field, each unit employing its own color.

The wastage of outpost wire was enormous. In an advancing movement it was folly to undertake to pick up the wire. The abandoned miles of it had to be left in the field to be salvaged later by the clean-up parties. The proposition of producing 68,000 miles of outpost wire every month staggered the wire manufacturers of the country. There were not enough braiding machines to complete such an order, and new ones had to be built before such a quantity of outpost wire could be attained.

In addition to the various means of communication, the Signal Corps was also called upon to supply in large quantities such other articles as wire reel carts, flagstaffs, field glasses, photographic equipment, chests, tools, meteorological apparatus, and wrist watches.

In the production of its supplies, the Signal Corps was confronted with the same obstacles of inadequate industrial capacity, dearth of raw materials, and congestion of railroad transportation that embarrassed almost every department of military production. To meet these difficulties the Signal Corps organized an elaborate inspection force which not only checked the work at the various factories for quality and rate of pro-

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duction, but was also constantly on hand to help the harassed manufacturer out of his difficulties as they arose. The Signal Corps never slept. At night and on holidays there was at least one officer on the job in Washington to receive telegrams or long-distance telephone messages and to be ready to act quickly in any emergency.

From the production standpoint, signal equipment was divided into several general classifications: (1) telephone and telegraph apparatus; (2) radio apparatus; (3) line-construction materials; (4) batteries; (5) wire and cables; (6) field glasses; (7) wire carts; (8) photographic supplies, pigeons and pigeon supplies; and (9) chests, kits, tools, mechanical signals, electric signals, meteorological apparatus, and wrist watches.

TELEPHONES AND TELEGRAPHS

In the early days of the conflict the construction of signal materials in the United States was devoted to such basic supplies as wire, cable, tools, and the standard types of telephone equipment, such as telephone sets and switchboards. The first great task in France was to install the lines of communication for the Services of Supply, a system that required American equipment because it was planned to operate it with American-trained telegraph and telephone operators.

Now, there were numerous styles of commercial telephone equipment manufactured in the United States. The plan was therefore adopted of allowing the various manufacturing concerns to bid on a tentative production schedule, giving an exclusive contract to the lowest bidder in each type of apparatus. This exceptional policy was adopted in order to avoid multiplicity of types of equipment to be used abroad. If many makes were adopted in each type, they would necessitate the procurement of many types of spare parts and replacement materials. The concerns which produced the telephone equipment for the American Expeditionary Forces were the Western Electric Company, of Kansas City; the Kellogg Switchboard & Supply Company, of Chicago; the Stromberg-Carlson

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Telephone Manufacturing Company, of Rochester; the Frank Black Company, of Chicago; and the Reliable Electric Company, of Chicago.

At the signing of the armistice there were 282 American telephone exchanges in France, with 14,956 telephone lines reaching 8,959 stations. The 282 exchanges ranged from the small four-line monocord unit, such as may be seen in any business office, to the standard American multiple board of the city telephone exchange. Of the last-named there were over thirty in use by the American Expeditionary Forces when the armistice was signed.

The special telephones adopted for use in the field were different from any in commercial use in America. The Signal Corps had developed certain special instruments combining both telephonic and telegraphic principles. The field telephone, Model 1917, for instance, was a telephone which included a telegraph buzzer on its telephone circuit. This instrument was used when great secrecy in communication was required. The messages were sent in telegraphic code, the buzzers being heard by the receiver. Another instrument was known simply as the buzzer. This was an instrument which utilized the telephone receiver for telegraphic messages. It was a supreme development for use over defective lines. An instrument which was closely related to the buzzer, but which gave even greater secrecy, was known as the buzzerphone. The buzzerphone was put into production just before the close of hostilities.

The mobile switchboard in most general use by our troops at the front—it was developed originally by the French—was known as the monotype. It was designed in units and could be extended to accommodate up to twelve trunk lines leading away from the board. This apparatus was the "central" of the front-line dugouts. It could be put into operation in a few minutes and was easily carried by a soldier. The switchboard of the dugouts was the only telephone equipment not of American design used by the American Expeditionary Forces. It was put into production in the autumn of 1917 in three American plants, under the general policy of the Signal Corps

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to contract with more than one factory for the production of any important device.

Another type of field switchboard, when packed for transit, resembled a salesman's trunk. It was used in the camps. It provided for forty lines. This board was being constantly redesigned as field needs developed. A new type of camp switchboard was coming into heavy production at the end of hostilities.

Still a third type of portable switchboard was built in units resembling the units of a sectional bookcase, and was set up in the same way.

The telegraph apparatus of the lines of communication in the Services of Supply was of a purely commercial type. It included the latest type of printing telegraph equipment, the apparatus first adopted being the multiplex printing telegraph as used by the Western Union Telegraph Company. Later the Morkrum printing telegraph was also adopted.

At the close of hostilities 133 complete telegraph stations with full equipment were in operation in the Services of Supply. The peak load of this service, just prior to the armistice, was 47,555 telegrams, averaging sixty words each, sent from these stations in a single day. The daily average in the final weeks of the fighting was 43,845 telegrams.

RADIO

At the outbreak of the war, the field radio equipment in active use by the Army was limited to two sets, both of comparatively high power. On the other hand, the Allied forces had developed a complicated and extensive use of radio sets of small power, many of them operated from airplanes, and the Signal Corps found itself confronted with the task of developing an entirely new line of complicated electrical apparatus and putting it into large quantity production in the shortest possible time. The progress made is indicated by the fact that at the signing of the armistice the number of types of complete sets on which development work had been carried out was seventy-five. Of these, approximately twenty-five were in

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quantity production. When it is known that each of these sets consisted of hundreds of parts, many of which required careful study and experimentation as well as design, the magnitude of the problem is appreciated.

The initial step in the reorganization of this branch of the Signal Corps' work consisted in the establishment of a radio section in Washington and a corresponding section in France. The former was charged with the design of apparatus and the preparation of manufacturing drawings and specifications; the latter served as the first-hand observer of actual service requirements and approved all equipment before it was used in the field. An important auxiliary of the development organization in Washington was the group of radio laboratories established at Camp Alfred Vail, where all necessary technical facilities, such as model shops, drafting rooms, research laboratories, a completely equipped flying field, and the like, were maintained. With this engineering organization and the production organization which handled all signal corps equipment, the work here detailed was carried out.

Shortly after the declaration of war, the French Government sent to this country a distinguished commission which included eminent radio experts thoroughly familiar with the latest military developments. Technical information and samples of radio apparatus were also obtained from British sources. With this beginning, the engineering work naturally divided itself into two general problems—first, to duplicate the approved foreign designs, and then to create designs for new types of apparatus which would be superior to any in service. Work on these two groups of problems was prosecuted simultaneously; and there were soon in production American equivalents of a number of French and British sets, together with improved original types of American radio apparatus.

Probably the most noteworthy technical development during the war, in so far as radio communication is concerned, was the extensive use made of vacuum tubes. These "bottles," which make practical use of the electrons of the new physics

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and which are sometimes called audions or pliotrons, are marvels in the realm of engineering, and their possible applications are as yet hardly realized. One form was used for the reception of signals prior to the war; but the military developments, particularly in France, had so progressed that when this country entered the war they were used both for receiving and transmitting signals, and most of the more important sets depended on them. To meet this demand the services of the three foremost vacuum-tube engineering organizations of the country were enlisted, and under the direction of the Signal Corps' radio engineers the progress toward satisfactory design and construction of the required types was rapid. Within less than six months standardized tubes were turned out by the quantity production method at rates sufficient to ensure the requisite supply. Work was continued, however, on the development of still better types of tubes. The improvements that were made from time to time were incorporated in the tubes being produced on a large scale.

As being indicative of the extent and variety of the radio development work which was carried on, there is given below a partial list of the types of sets which were completely developed and placed in production during the war period:

LAND RADIO EQUIPMENT

Spark sets, sending and receiving (three types)
Continuous-wave army radio telegraph sets (three types)
Radio telephone set (one type)
Tank radio telegraph set (one type)
T. P. S. (earth telegraphy) (four types)
Wavemeters
Battery-charging sets
Radio operating and repair trucks
Miscellaneous special equipment

AIRPLANE RADIO EQUIPMENT

Interphone sets (for use of two to five persons)
Radio telephone sets (three types)
Radio telegraph sets (three types)
Direction-finding radio-receiving set (one type)

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Photo from Signal Corps

MILITARY TELEPHONE SCHOOL AT UNIVERSITY OF MICHIGAN

Photo from Signal Corps

SIGNAL EQUIPMENT INSTALLED IN DUGOUT

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Photo from Signal Corps

SOLDIERS STUDYING PRINTING TELEGRAPH AT COLLEGE OF THE CITY OF NEW YORK

Photo from Signal Corps

FIELD WORK WITH RADIO

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The magnitude of the production of special items involved may be gathered from such figures of expenditures as the following:

For vacuum tubes	$1,650,600
For storage batteries	5,315,350
For dry batteries	602,470
For battery-charging sets . . .	1,524,400

These are, of course, only some of the items. The total production authorized was valued at approximately $45,000,000.

The remarkable development and improvement of military radio equipment which took place under the direction of the Signal Corps during the war will undoubtedly materially change the system of army communications and even the tactical use of military equipment and *personnel.* A typical example of this development was the airplane radio telephone, described elsewhere, the use of which has made possible the "voice-commanded air squadron." The military value of an air squadron has been enormously increased by virtue of this device, which enables the squadron commander to direct the movements of the individual airplanes in any manner which circumstances may require.

Certain other radio devices recently perfected, the purport of which can not be revealed, will undoubtedly affect the tactical use of troops to such an extent as to make certain kinds of radio equipment as indispensable to the operations of military units as the rifle or the machine gun.

LINE EQUIPMENT

The first requisition of line equipment for France called for the construction of 500 miles of telephone and telegraph main pole lines, carrying ten copper telephone and telegraph wires. It was found that ship space could not be spared for poles in such quantity. Consequently a forestry unit was sent to France to get these poles from the French woodlands. All the other materials for the 500 miles of line, together with materials for approximately 600 miles of extensions, were procured in

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the United States and shipped to France within six months after the requisition was received. This material was secured in so short a time only by the coöperation of the large commercial companies in the United States, who literally stripped their warehouses bare.

In the late summer of 1918 the American Government began anticipating the advance of the Allied forces into Germany, and the Signal Corps put into production a reserve equipment for a long-distance line approximating 500 miles. Soon there was received from France a cablegram asking for the shipment of this material, and it was all floated before the armistice. As it turned out, however, this equipment was never required, for the terms of the armistice gave the American forces the German telephone and telegraph lines in the occupied territory.

This line equipment was all of a type standard in the United States. For the fighting zone, special line equipment was required. Before the war with Germany, American signal troops had set up their emergency telephone and telegraph lines on the standard "lance poles." These poles served admirably in open warfare, but proved to be impracticable for the static conditions of fighting in France. After a considerable supply of lance poles had been shipped abroad their production was curtailed. Thereafter the trench telephone and telegraph lines were supported on short stakes with special cross arms, in appearance the conventional telegraph poles in miniature. The enormous mileage of trench lines called for a great quantity of insulators and cross arms. The wastage of these fittings, due to their being exposed to artillery fire, became increasingly greater in the closing months of the war.

In wire itself, the American production was enormous. This production included the commercial type of copper line wire and the drop wire for connecting individual telephones to the pole lines. Much commercial cable for connecting congested centers with branch switchboards was also required. Yet all the wire used in the system within the Services of Supply was but a small quantity compared with the requirements in the fighting zone.

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The production of double-conductor wire, or the so-called outpost wire of No Man's Land, which had relegated to the scrap heap the standard field wire of open warfare, necessitated an extraordinary effort. The wire had to be light enough for easy transportation and laying, strong enough to withstand the abrasions from traffic crossing it as it lay on the ground, and exceedingly well insulated. The first estimate was that an American army in the field might use 1,000 miles a month of outpost wire. When the first American force actually went into action, in the spring of 1918, a reserve supply of 20,000 miles of outpost wire was in the American warehouses in France, with a vast quantity of cable in reserve. Cable, at first used in large quantities at the front, was invariably buried several feet underground and abandoned at every change of headquarters.

As the fighting grew more intense and covered a wider and wider area, the wastage of outpost wire became enormous. The demand of our forces for cable dropped to a negligible quantity, but wire requirements rose. Outpost wire became the main dependence of ourselves and the Allies for all communication in the active sectors. A higher quality of wire was specified. So great was the destruction of wire that by July, 1918, the original estimate of 1,000 miles a month to be supplied by American factories had jumped to 20,000 miles.

As a substitute for outpost wire to fill the immediate needs, the familiar twisted drop wire, with which the ordinary telephone is connected with the main circuit, was adopted. Our field officers liked drop wire, its only objectionable feature being its comparative bulk. All available drop wire in the United States was shipped across, and its manufacture was pushed until the new type of outpost wire could be produced. The Signal Corps supplied the mounting needs of the American Expeditionary Forces through August and September, 1918, with the available drop wire plus the growing production of the new outpost wire. In early August all the wire makers in America were summoned to a conference, in which the Signal Corps made known the necessity of pushing production. The result was an expansion which reached a total

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production of 40,000 miles of outpost wire in November. Just before the armistice was signed, the American Expeditionary Forces indicated that they would require 50,000 miles of outpost wire every month, beginning in January, 1919. This requirement had already been fully anticipated, since the American manufacturers had set for themselves a maximum production of 68,000 miles a month by August, 1919. To secure this production every wire mill in the United States worked twenty-four hours a day. When the production was at its height, enquiries came from the Allied governments, indicating that they should call on American wire makers for a quantity of wire equal to what they were already producing for the American Expeditionary Forces. In other words, this proposition called for the doubling of a production which had already attained great size. Yet, had the fighting continued, there is every reason to believe that the industry would have risen to the demand.

The production of outpost wire was an intricate operation. To fill the demand for 50,000 miles of outpost wire a month called for 300,000 miles of steel strand and 400,000 miles of bronze strand every month. The steel strand had to be given repeated heat treatments before it had acquired the necessary tensile strength.

ELECTRIC BATTERIES

The American Expeditionary Forces consumed great numbers of electric batteries, the familiar dry battery of commerce being most used. Toward the end of the fighting, arrangements were being made to establish in France a plant at which dry batteries would be assembled by French labor, utilizing parts made in America. The necessary apparatus and materials for the first operation had reached France before the armistice, but the plant was not in production at that time.

Storage-battery requirements of the American Expeditionary Forces were heavy and exacting. The storage battery was the only practicable source of electrical energy for the operation of small portable radio outfits. Field conditions required

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a storage battery that would not spill its contents, in a jar not easily broken, the whole equipment to be as light as possible. A rubber composition jar was finally adopted.

The chief reliance of the American Expeditionary Forces was on storage batteries of European manufacture, which were to be used until American production got under way. When, by the summer of 1918, America had perfected her own designs of radio equipment, the Signal Corps took up storage batteries for radio and decided upon types. This was in July, 1918. A conference of battery manufacturers was called and the orders were allocated among practically all the storage-battery plants in the United States that were in a position to undertake quantity production. The end of hostilities stopped this production on the eve of heavy deliveries.

FIELD GLASSES

When the war began, the Signal Corps had the duty of providing field glasses for all branches of the Army, issuing them to noncommissioned officers and selling them at cost to commissioned officers engaged in combat. The first estimates showed that these glasses would be needed by tens of thousands, whereas the manufacturing facilities in the United States had turned them out merely by hundreds. The optical-glass industry had never been developed in America, our field glasses being supplied with lenses of European glass, and principally German glass. In 1914 the imports of optical glass were $641,000 in value. The following year they were almost nothing. The advance of the German Army toward Paris encompassed the glass plants of Belgium and many of those of France. England needed the entire output of her own glass factories.

In the autumn of 1914 the American optical-instrument makers began to develop an optical-glass industry, largely stimulated by the possibility of obtaining heavy orders at high prices from the British, French, and Russian governments. The most important work was done by the Bausch & Lomb Optical Company, of Rochester, New York, the Spencer Lens Com-

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pany, of Buffalo, and the Pittsburg Plate Glass Company, of Pittsburg. They were aided by the United States Bureau of Standards and by the Geophysical Laboratory of the Carnegie Institution. The Bureau of Standards established a laboratory at Pittsburg in which experiments were conducted with 30-pound pots of glass.

Optical glass differs greatly from ordinary glass. It must be clear, without striæ, and there must be no strains in it such as result from the final stirring and cooling. It must give a high transmission of light. About the time of America's declaration of war the American experiments had produced glass suitable for optical instruments. This glass, however, was being turned out in quantities quite insufficient to meet the demand during the first few months.

In addition to the difficulties surrounding the glass supply, there was only a limited number of establishments capable of manufacturing field glasses after the glass was procured. These concerns were located principally in Rochester, New York, where they had been manufacturing a wide variety of optical instruments, including opera glasses, camera lenses, scientific and educational apparatus, battery commanders' telescopes, marine glasses, microscopes, and gun sights. In order to meet the war requirements of America for field glasses, these factories had to install large quantities of new equipment and to run day and night. The equipment consisted of lens-grinding apparatus, lathes, dies, and automatic screw machinery.

In addition to the Rochester factories there was a concern in Denver, Colorado, the Weiss Electrical Instruments Company, which, in a smaller way, had been manufacturing surveyors' levels and other engineering apparatus. The Talbot Reel & Manufacturing Company, of Kansas City, had been making fishing reels in a small plant about thirty feet square. This factory was purchased in 1917 by Mr. L. Harris, who, after finishing a contract for gun sights for the Ordnance Department, built a factory especially for the production of army field glasses and reached the quantity manufacture of these instruments before the armistice came. The chief center of supply, however, con-

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tinued to be Rochester, where the plants of Bausch & Lomb, the Gundlach-Manhattan Optical Company, and the Crown Optical Company were located. These factories expanded many times, and the output of field glasses went beyond what the executives at the outset of the enterprise imagined could be possible.

The Bausch & Lomb Company was started in Rochester about fifty years ago by J. J. Bausch, who was born in Germany. The plant developed gradually, making a full line of spectacle lenses and optical instruments. The Carl Zeiss Works, of Jena, Germany, had a financial interest in the plant, and Bausch & Lomb had a financial interest in the Zeiss plant. This connection, however, was dissolved in 1915, when Bausch & Lomb took on contracts for the manufacture of field glasses for the British, French, and Russian governments. Before 1914 this concern had never manufactured more than 1,800 pairs of field glasses in a year. The output was speeded up until in November, 1918, a total of 3,500 pairs was being produced each week, and the development was aiming toward an output of 5,500 pairs of glasses a week beginning in January, 1919. At the date of the armistice the Bausch & Lomb factory had a floor space of thirty-two acres and employed 6,000 men and women.

The Gundlach-Manhattan Company, which had made camera lenses chiefly, was eventually able to produce 600 pairs of field glasses a week. The Crown Optical Company was not so rapid in its expansion; and in late 1917 the Navy Department commandeered it and thereafter operated it in charge of Lieutenant Commander L. C. Scheibla. Under naval management the output of this factory so increased that the Signal Corps was able to obtain from it about 1,200 pairs of high quality field glasses each week, the plant continuing also to supply the needs of the Navy.

Out of a situation that seemed impossible at the outset, the Signal Corps within a comparatively few months built up an industry which provided all the field glasses that were necessary in the operations of the American Expeditionary Forces.

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Often, to keep the optical factories equipped with sufficient workmen, the Signal Corps obtained the furlough of drafted men with experience in this field so that they might go to work making field glasses.

All army organizations except artillery were supplied with a six-power glass having an angular field that took in a view 150 yards wide at a distance of 1,000 yards. The glasses were of the prismatic type with individual focus for each eye. Each glass was provided with a leather carrying case and shoulder strap. On the top of the case a compass was mounted.

The artillery organizations were supplied with eight-power field glasses, all of which were purchased in France.

The total requirements of the American Expeditionary Forces for field glasses of the six-power type during the period of hostilities were approximately 100,000 pairs. The total shipments from America were approximately 106,000 pairs.

MISCELLANEOUS SUPPLIES

The Signal Corps took up with three concerns—the Hampden Watch Company, the Illinois Watch Company, and the Elgin Watch Company—the matter of providing wrist watches for the Army. A 7-jewel movement was adopted as standard for issue to troops and a 15-jewel movement for sale to officers. A waterproof case was adopted, bearing the serial number of the movement on the outside, and the case was so constructed as to require a special tool to gain access to the movement.

The production of wire carts for the Signal Corps did not exceed twenty-five a year before 1917. The demand for these carts, which were hard to build, increased at such a rate that during the autumn of 1918 the matter of procuring them was one of the most serious production problems faced by the Signal Corps. The Holmes Automobile Company, of Canton, Ohio, abandoned the production of automobiles and in September, 1918, turned over its entire plant to the production of wire carts. Other manufacturers were the George B. Marx Company, of Brooklyn; the J. G. Brill Company, of Philadelphia; the American Instrument & Tool Company, of New

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York; and the Wesel Manufacturing Company, of Brooklyn. In all, 721 wire carts were manufactured and 327 shipped overseas.

A total of 2,402 tool chests for the Signal Corps was produced during the war period. The plan eventually adopted was to split up the orders for tools among the various manufacturers and to give the manufacture of the empty chests to prison labor at Fort Leavenworth, where the tools were to be shipped and packed in the chests. This plan, however, required the construction of a special building at Fort Leavenworth, and in the meantime the assembling of tool chests was conducted at the signal corps supply depot at Philadelphia and at the port of embarkation. The armistice stopped the construction of the assembling factory at Fort Leavenworth.

The Signal Corps produced a suitable number of gas alarm signals known as strombos horns. This equipment consisted of an alarm horn operated by air pressure acting against a diaphragm and thereby producing a loud and distinct chatter. Compressed air was supplied in small steel cylinders connected to each horn by hose. The air tanks were charged behind the lines from a portable air compressor which could pump into several cylinders at once. The horns were manufactured by the Klaxon Company, of Newark, New Jersey, the cylinders by the Harrisburg Pipe & Pipe Bending Company, Harrisburg, Pennsylvania, and the air compressors by the Ingersoll-Rand Company, of New York.

Flag kits were not used to any great extent by the American Expeditionary Forces, although large quantities of them were produced in this country.

The Signal Corps originally had jurisdiction over all war photography, either of land or air, except for a small amount conducted by the Engineers in connection with their own operations; but aërial photography became later the exclusive function of the Air Service. After that the Signal Corps was charged with taking all photographs of historical or other interest. In connection with this work two types of cameras were necessary—still cameras and motion-picture cameras.

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Late in the war there was being developed a new motion-picture camera which was expected to be the ideal type for use in the field.

It was with great difficulty that a sufficient number of photographic lenses was obtained for the use of military cameras, for the large lens factories of America were tied up with other war orders. A campaign conducted by the leading newspapers and magazines of the country resulted in the Government's securing from amateur photographers a large number of high-grade lenses, mostly of foreign manufacture.

The Signal Corps scattered its camera operators broadcast over the country, photographing cantonments and other war activities to the most minute details. These photographs and films were then made public in newspapers, periodicals, and motion-picture theatres throughout the United States, so that the people saw with their own eyes how their soldiers were preparing for the defense of the nation. An interesting development of war photography was the production of motion pictures showing the training of soldiers. Many pictures were taken to show graphically on the screen the different chapters of the army drill regulations. These pictures will have a future use to the Government in training soldiers efficiently in the shortest possible time. The signal corps photographers also developed a new kind of history of the war, a history written entirely in pictures for future generations to scan.

PIGEONS

Although nearly every European army for forty years has trained the carrier pigeon to be a field messenger, the American Army never adopted the bird until 1917. In a single year the Signal Corps established hundreds of pigeon lofts in this country and overseas and bought and trained more than 15,000 pigeons for service in France. In actual use on the field the pigeons delivered more than 95 per cent of the messages entrusted to them, flying safely through the heaviest shell and gas barrages.

The standard pigeon loft adopted by the Signal Corps had

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a unique trap arrangement which permitted the entry, but not the exit, of returning pigeons, and an electrical alarm which automatically notified the attendants of an arrival. Such lofts, however, were of the stationary type and not practicable for use in France. For the American Expeditionary Forces the Signal Corps purchased mobile lofts. It was found that pigeons would come home as well to mobile lofts, which were constantly changing position, as they would to stationary lofts. The first mobile lofts built in the United States were top-heavy, but this defect was overcome by increasing their width and adding heavier wheels. They were all built by the Trailmobile Company, of Cincinnati, Ohio.

Civilian pigeon fanciers were appealed to and urged to breed young birds to stock the government lofts. The Signal Corps distributed small aluminum bands to be put on the legs of squeakers (as the newly hatched pigeons are called) which were intended for sale to the Government. The uniform price of $2 a bird was paid, and over 10,000 youngsters were bought for stocking purposes.

Tons of pigeon feed were purchased and shipped to Europe. Some of this grain, such as millet, Argentine corn, pop corn, hempseed, and Canada peas, was hard to obtain; but nevertheless, the supply was well maintained. It was shipped in hermetically sealed containers to prevent it from becoming mildewed.

The American Army copied the French and English models of willow and reed baskets to hold the birds. One type of basket, carried on the back of a soldier, contained small corselets in which the pigeons were securely fastened. Corselets were suspended from the sides of the basket by elastic contrivances permitting considerable joggling without injury to the birds. All these baskets were made by the A. L. Randell Company of Chicago.

Message books were manufactured in accordance with a French model. After the message had been written, it was placed in an aluminum capsule which fitted in a holder of aluminum. This holder was attached to the pigeon's leg by

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aluminum bands. These bands were found to break easily, and pure copper bands were later substituted. The message holders were manufactured by Thomas A. Gey, of Norristown, Pennsylvania.

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CHAPTER XXIX

FOOD

WHEN the American soldier went to war against Germany he took his appetite with him. The task of keeping that appetite satisfied with good food (and the soldier, therefore, contented and well) fell to the Quartermaster General. The average American soldier at the end of the fighting in 1918 is said to have weighed twelve pounds more than he did when the Selective Service Act or his own enlistment brought him into the Army. This is the ultimate testimonial to the quality and quantity of the food served to the American troops in 1917 and 1918. Assuming 3,700,000 to have been the greatest number of Americans under arms, this average increase in weight means that the beans and bacon and fresh meat of the American army ration were transmogrified into some 45,000,000 pounds of Yankee brawn, the basis of untold resources of health and energy during the coming quarter of a century.

Consider these millions of soldiers as one composite, gigantic man in khaki; compress the war period into a single hour, the dinner hour; and it will be seen that the American fighter consumed what might be called a sizable meal. Let us say that he started off with the main course. The roast beef weighed over 800,000,000 pounds. It was flanked by a rasher of bacon weighing 150,000,000 pounds. Over 1,000,000,000 pounds of flour went into the loaf of bread; and to spread the bread there was a lump of butter weighing 17,500,000 pounds and another lump of oleomargarine weighing 11,000,000 pounds. As a side dish this giant had over 150,000,000 pounds of baked beans, half of them in cans ready baked and flavored with tomato sauce. The potatoes weighed 487,000,000 pounds. To add gusto to his appetite there were 40,000,000 pounds of onions.

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Then, scattered over the table were such items as 150,000,000 cans of corn, peas, and string beans; and the salad contained 50,000,000 cans of salmon and 750,000 tins of sardines. There was a huge bowl of canned tomatoes, nearly 190,000,000 tins supplying its contents. For dessert he had 67,000,000 pounds of prunes and 40,000,000 pounds of evaporated peaches and apples. The sugar for sweetening various dishes weighed 350,000,000 pounds. He washed it all down with a draft made of 75,000,000 pounds of coffee thinned with 200,000,000 cans of evaporated milk. The bill for the meal, paid by the American public, amounted to $727,092,430.44 up to December 1, 1918.

In supplying such vast quantities of food, scientific attention was concentrated upon the details of the effort. At the time the armistice was signed, the American troops in France were eating about 9,000,000 pounds of food every day. Never before in history had any nation been compelled to send subsistence so great a distance to so many men. It was not possible to ask France and England to divide their food supplies, for they were already rationing their civilian populations. We were required to purchase practically all food in America and transport it nearly five thousand miles. Ships were relatively scarce. There was a strong bid for every inch of tonnage space. The tonnage allotted to subsistence had to be filled with sufficient food not only to supply the immediate consumption, but also to overcome losses due to the sinking of ships and the possible capture of base depots. These contingencies required two pounds of food to be shipped where one would ordinarily be sent; yet, because of the shortage of ships, the subsistence authorities were asked to pack these two pounds into little more than the space of one. The result was foods in forms never before known by American soldiers and in some cases never before known at all—such forms as dehydrated vegetables, boneless beef, and the so-called shankless beef. Trench warfare made new demands for food. Calls came for such rare articles as soluble coffee or the wheat-and-meat cake of the emergency ration. These problems were solved only by the assistance of the American food industry. In numerous in-

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stances new factories, or even whole new types of food manufacture, were built up as rapidly as three shifts of men could work and money accomplish results.

The cost of food rates high among the war costs of 1917 and 1918. Back in 1897 the average meal in the Army cost about four cents, and the daily three meals thirteen cents. At the end of 1918 the cost of the ration was approximately forty-eight cents. The advance was not all due to the advance in living costs. Much of it was on account of the improved standards of the ration. In 1916 Congress appropriated $10,000,000 to feed the Army; the fiscal year beginning July 1, 1918, brought an appropriation of $830,000,000 for the same purpose.

The American fighting man of 1917-1918 was a good feeder. He ate nearly three-quarters of a ton of food each year, or over ten times his own weight. Without counting at all any transportation costs or the expense of handling, each man's yearly supply of food cost more than $165. In spite of the most rigid and painstaking economies in the purchase of this subsistence, the American people were paying, at the peak of army expansion, more than $2,500,000 a day to feed the troops.

The distance of the American Expeditionary Forces from the source of their food supplies required that their food be largely purchased in nonperishable forms. That is, meats had to be cured, meats and vegetables tinned, vegetables and fruits dried. We paved the way to Berlin with tin cans. The various foods put up in tins and purchased during the year 1918 totaled over 1,000,000,000 cans, or enough, standing on end, to make a road wide enough and long enough for a force of men marching in columns of four to go from the port of embarkation at Hoboken, New Jersey, to the heart of Germany. The largest closing machine can seal 240 tin cans a minute. If such a machine could be operated eight hours a day seven days a week, it would take it twenty-three years and six months to seal these tins.

During the spring of 1918, when the demand for men in France resulted in reducing the available tonnage for supplies,

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the cry came from France to cut every nonessential. As a result, most of the canned vegetables and fruits, including peas, corn, sweet potatoes, asparagus, pineapple, pears, and apples, were stricken from the list of food supplies for the American Expeditionary Forces. From France came calls for tomatoes and men, men and tomatoes. This phrase did not mean that bread and bacon, beans and beef should be eliminated; but it emphasized the importance of this one vegetable, the tomato. The total purchases of tomatoes exceeded those of all other vegetables combined. In addition to the many ways of serving tomatoes, they were used in the trenches to relieve thirst, being, perhaps, more effective than any other substitute for water. A quart of tomato juice, because of its food value and slight acidity, was worth several quarts of water to the thirsty men in the field. The Army took 45 per cent of the total 1918 American pack of tomatoes. These tomatoes were bought from 5,000 firms scattered throughout the rural districts of the United States.

The demands of the overseas forces for meat during the summer of 1918 were so heavy that they created a shortage of beef in the United States. Beef was the mainstay of the soldier's diet. The Army allowed 456 pounds of beef a year for each soldier. This does not mean that the soldier actually ate that amount of beef: beef was simply the Army's meat standard. Pork, usually in the form of bacon, was substituted for 30 per cent of this quantity of beef, twelve ounces of bacon being considered the equivalent of twenty ounces of beef. The major portion of the American Expeditionary Forces' beef was fresh beef shipped frozen all the way from the packing plants in the United States to the company kitchens at the front, through an elaborate system of cold-storage warehouses and refrigerator cars and ships.

The Food Administration asked that the people substitute corn meal, rye flour, and other grain flour for 20 per cent of the wheat flour ordinarily used in making bread. The troops in the United States complied with this ruling and saved 1,000,000 barrels of flour. The use of substitutes in France was not

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insisted upon, for bread making in the field is more difficult. Field bakeries were not adapted to such experimenting with doughs and yeasts as must be done when substitutes for flour are used. The army allowance of flour for a year for one man was 410 pounds. Flour was usually issued in the form of bread, one pound of bread being allowed each man each day. Other yearly allowances were 56 pounds of beans, 27 pounds of prunes, 27 pounds of coffee, 73 pounds of sugar, 11½ pounds of condensed milk, 3½ pounds of vinegar, and 13½ pounds of salt. For variety, other items were specified which might be substituted for these foods.

Food was purchased by the Quartermaster Department and furnished to the individual companies at cost. In charge of the mess was a sergeant, who had had special school instruction as to methods of feeding the Army. The mess sergeant checked over his stocks daily and made up a list of what he should require for the coming day. This list was given in turn to the camp supply officer, under whose direction the order was made up and delivered to the kitchen on army trucks.

This order was based on a ration allowance, as has been stated, a ration being the food required to subsist one man for one day. The general components of the overseas camp ration consisted of the following:

Component articles and quantities			*Substitutive articles and quantities*		
Beef, fresh . . .	ounces	20	Mutton, fresh . .	ounces	20
			Beef, fresh, boneless	ounces	16
			Bacon	ounces	12
			Pork, fresh . . .	ounces	16
			Sausages, canned pork or Vienna	ounces	16
			Canned roast beef or corned beef	ounces	16
			Hash, corned beef .	ounces	16
			Fish, dried . . .	ounces	14
			Cheese, not exceeding 10 per cent of total issue	ounces	10
			Fish, canned . . .	ounces	16
Bread, soft . . .	ounces	16	Flour, corn meal, oatmeal, or macaroni, in lieu of an equal quantity of bread, but not exceeding 15 per cent of total issue.		

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Component articles and quantities			*Substitutive articles and quantities*		
Baking powder (to be issued only with flour or corn meal, 1 ounce to 20 ounces)	ounce	.08			
Beans, dry (not to exceed 4 issues in 10 days)	ounces	4	Beans, baked (not to exceed 4 issues in 10 days)	ounces	8
Rice or hominy (not to exceed 6 issues in 10 days)	ounces	2			
Potatoes, fresh . .	ounces	20	Onions, fresh, in lieu of an equal quantity of potatoes, but not exceeding 20 per cent of total issue. Tomatoes, canned, in lieu of an equal quantity of potatoes, but not exceeding 20 per cent of total issue.		
			Canned potatoes .	ounces	15
			Other fresh vegetables (not canned) when they can be obtained in the vicinity by purchase or from the U. S. Garden Service, or can be transported in a wholesome condition from a distance, in lieu of an equal quantity of potatoes.		
			Dehydrated vegetables to be issued only in case fresh vegetables are not available	ounces	4
			Corn, canned . .	ounces	12
			Peas, canned . . .	ounces	20
Jam	ounces	3	Prunes, or evaporated apples, or peaches, or apricots, or figs, or dates, or raisins, in lieu of an equal quantity of jam.		
			Sirup	gill	.64
Coffee, R & G . .	ounces	1.12	Tea, black or green	ounce	.32
Sugar	ounces	3.2			
Milk, evaporated, unsweetened	ounce	1			
Vinegar	gill	.16	Pickles, cucumber, in lieu of an equal quantity of vinegar.		
Salt	ounce	.64			
Pepper, black . .	ounce	.02			
Cinnamon . . .	ounce	.014	Cloves, or ginger, or nutmeg, or sage, thyme, or allspice	ounce	.014

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Component articles and quantities			*Substitutive articles and quantities*		
Butter	ounce	.5	Oleomargarine, or lard, or lard substitute .	ounce	.5
Flavoring extract, vanilla	ounce	.014	Flavoring extract, lemon	ounce	.014
Candy (issued ½ pound once in 10 days) . .	ounce	.8			
Tobacco, smoking (100 cigarette papers for each 4 ounces smoking tobacco)	ounce	.4	Cigarettes . . .	ounce	.4
			Tobacco, chewing .	ounce	.4

The ration at home was practically the same. The home ration, however, did not include candy and tobacco. The commanding officer had authority to modify or change all rations to meet special conditions. For instance, in times of great cold and when the men were subject to great exposure, or after long and tedious campaigns or marches, or when the work required of the troops was abnormal, the ration might be increased. The ration also included soap, candles, matches, towels, and a few other items considered necessary in the daily life of a soldier. The value of a ration fluctuated with the market from month to month. Each day's food weighed about 4.6 pounds *per capita.*

The men actually in the trenches sometimes made use of the emergency ration, the little flat can of compressed nourishment which every soldier carried in his pocket. This ration, however, was used only in severe straits, on the order of an officer, or on the enlisted man's own responsibility in the direst emergency, when the activity of the enemy made it impossible to get hot food to the men during daylight hours. Hot food was served in the trenches whenever possible. The hot food consisted principally of soups and soluble coffee. Specially constructed cans, made on the principle of thermos bottles, kept the food hot while it was being carried to the front. The chief quartermaster of the American Expeditionary Forces relates that on a tour of inspection made by him during the Argonne-Meuse offensive, on November 1, 1918, he inspected the meals served at noon to the troops of the Fifth Corps actually engaged in battle on that day, and found in a number of instances that artillery organizations were being served beefsteak, pota-

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toes, onions, tomatoes, white bread and butter, rice pudding, and hot coffee, the men eating in reliefs in order that there might be no cessation of fire. The hot meals for the infantry were prepared at their rolling kitchens a short distance to the rear of the line, and sent forward to them in "marmite" cans.

The company was the unit on which the feeding of the men was based. Each month the company was given credit at the quartermaster's store equal to the number of men in the company multiplied by thirty times the ration allowance. On the basis of this credit the mess sergeant of the company made purchases to feed his men. He might be as economical as he desired, provided that he fed the men sufficiently. If the entire credit extended him at the camp quartermaster's office were not used up during the month, a check was given for the difference. This went into the company's funds, with which the mess sergeant might buy in the open market such extras and delicacies as the savings would permit, up to the quantity specified in the ration. But this system was followed only in the United States. Savings were not allowed in France, all food there being issued on a straight ration basis. This policy was adopted because the shortage of tonnage made it imperative that no article not absolutely essential be shipped from the United States. Difficulties of transportation in France, too, necessarily eliminated all except the most essential articles of food.

Under the procedure in vogue just previous to the recent war, subsistence was purchased by depot quartermasters located in thirteen principal cities throughout the United States. The plan gave the Army a large number of purchasing officers for subsistence, working without coördination and even in active competition with each other. This condition resulted in a wide range of prices and a lack of uniform quality; and under war conditions, with the enormous quantities to be procured, it would cause at times a congestion of buying orders, with consequent disturbance of market prices. A plan of control was soon worked out whereby the Subsistence Division, with headquarters at Washington, received at regular intervals the estimates of needs for army subsistence both at home and abroad.

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These estimates were compared and a budget made up. Bids were then asked through zone supply officers, who reported the bids to the control body in Washington. The lowest or most advantageous bid was accepted, and the purchase was completed by the zone supply officer in whose zone the seller was located. The plan eliminated one army zone's bidding against another. At the same time it enabled every manufacturer or producer to bid on the needs of the Army. In this way active competition was secured and low prices were obtained. A decided advantage of the plan was that purchases were made with a minimum of disturbance to prices paid by the civilian trade.

It was found that the independent buying of the Army, the Navy, and the Allied Provision Export Commission was having the effect of increasing prices of a number of food products. These buying agencies were bidding against each other. In December, 1917, at the suggestion of the Food Administrator and with the consent and approval of the Secretary of War and of the Secretary of the Navy, the Food Purchase Board was organized to coördinate all the domestic purchases of food products intended for military purposes. The plan adopted was to allot through the Food Administration the required quantity to the industry producing the commodity in question, dividing the business among the various producers in proportion to their capacity. Products so controlled were those in which there was an actual or prospective shortage. The prices were determined by the Food Purchase Board after studying and investigating the costs of production. The products so purchased included flour, sugar, all canned vegetables, canned and evaporated fruits, salmon, sardines, canned milk, rice, and, for a time, fresh beef. These products totaled about 40 per cent of all food requirements for the Army.

Practically all purchasing of meat was done by the Subsistence Division's packing-house branch, located in Chicago. Circular proposals were submitted by the various packers whose headquarters are located there. The Subsistence Division or-

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dered the required purchases made, and the Chicago office at once allotted the amount needed among the packers. After the butchering and inspection of the meat, it was sent to the freezers and, after being frozen, loaded into cars and shipped to embarkation points. The whole process from the time the animal was killed until it was loaded on the boat took about two weeks. The Middle West produced practically all the beef which nourished our fighting men. Some of the cattle were bought in California, inspected at the packing-house plants along the Pacific coast, and sent to France *via* the Panama Canal. The packers of Chicago and other cities found their plants, gigantic as they were, all too small to handle the demand of our troops for meat products packed in special forms; and extensive additions, both in buildings and machinery, were made necessary by the Army's demands.

It was only by careful vigilance on the part of its inspection branch that the millions of men dependent on the Subsistence Division for their food were protected from deterioration of supplies and abuses by certain dealers and manufacturers. Such firms were in the minority, for the food industry backed the Army with great loyalty, giving honest and patriotic support. But in a certain week the inspection service found oatmeal flour moldy and unfit for use, having been stored too long before using; large amounts of potatoes, shipped to Camp Devens, undersized and frostbitten; 3,000 pounds of butter at Camp Greene too old for use; and twelve carloads of tomatoes of poor quality. The system in vogue of demanding reinspection was responsible for discovering such cases, and traveling inspectors also kept the products up to the highest standard. Any information from outside sources was immediately investigated. Samples of all shipments of foodstuffs were required to be sent to the inspection branch. In this way many violations of the food laws were found. One packer was found to be using pork which contained large numbers of skippers. Another tried, consciously or unconsciously, to pass off wormy dried fruits. Milk was in some instances found to be much below standard. All these supplies were promptly

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rejected as unfit for army use. Often the fault was found to be the result of improper manufacturing conditions, and in such circumstances the manufacturer was compelled to make good the loss to the Army. The general result of this inspection was that manufacturers gave the Army their best products.

One of the most important divisions of the inspection branch was the meat and meat-products section. Its function was the supervision of the reinspection, storage, and handling of meat and meat products, butter, and cheese. Special care was taken to see that there were no embalmed meats. Meat and meat products, butter, and cheese are all highly perishable articles; and, although they may be delivered in perfect condition, many imperfections may develop if diligent care is not exercised during shipment, handling, and storage. One of the first steps taken at the camps was the installing of complete cold-storage plants with adequate chill rooms, so that the proper preservation of fresh meats was assured after arrival at camps. From the first the most rigid inspection of meat and meat products was insisted on and no product allowed to pass which did not comply with army specifications. The carcass might be from a perfectly healthy animal, yet be rejected, as lightweight carcasses were not approved for consumption in the Army. Instructions as to army requirements, covering the inspection, storage, and handling of meat and dairy products, were placed in the hands of every inspector. Supervisory traveling inspectors visited all stations at irregular intervals to ensure that these instructions were followed and to instruct quartermasters in posts which were too small to warrant a qualified meat inspector being stationed there.

One object of the Subsistence Division was to educate the proper officers throughout the Army to be inspectors. To accomplish this object, the inspection branch compiled a manual covering practically all the principal items of army subsistence, the exact methods of inspection, and how to detect imperfections in foods. Complete army specifications for all supplies were included. General Pershing cabled for 250 copies to be used in France, and the University of California adopted

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the manual to be used in its zymology classes. The manual placed exact knowledge in the hands of the men who received the food and who had the responsibility of seeing that it was up to specifications.

The overseas forces were the primary concern of the Subsistence Division. It was planned to have approximately three months' advance supply of food sent over each month for the number of troops actually sent to France during that month. This was called the initial supply. In addition to this, there was sent over a monthly automatic supply, equivalent to the amount of food the troops already in France would consume during that month. In this way a ninety days' reserve was usually maintained overseas.

The problems of the overseas forces demanded quick solution. The new modes of warfare gave rise to many needs unknown in peace times. Calls came in for commodities which were not at the time being produced in adequate quantities. Factories had to be built, labor secured, and machinery manufactured; in instances, entirely new industries had to be created.

The Services of Supply found it impossible to secure sufficient fresh vegetables in Europe to take care of the requirements of our troops, and the Subsistence Division at home was called upon to supply dehydrated vegetables for overseas requirements. To send fresh vegetables from the United States was impossible, because of the great necessity for conserving ship tonnage, and a substitute was imperative. To supply dehydrated vegetables meant the development of an industry. Dehydration was practically unknown in the United States, there being but three small plants in existence. The Subsistence Division searched the country for advantageous locations where there were prospects of having such factories established. Within a few months the coöperation of companies was secured and factories were built whose combined output for the month of December, 1918, amounted to 6,000,000 pounds, there being fifteen large plants in the United States by that

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HASH FOR SOLDIERS

Photo from Quartermaster Department

CANNING FRUIT FOR THE ARMY

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THE HOME OF "CORNED WILLIE"

Photo from Quartermaster Department

PACKING TOBACCO ON ARMY ORDERS

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time. Up to the date of the armistice 62,000,000 pounds of dehydrated vegetables had been ordered by General Pershing.

The difficulty of supply was increased by the delicacy of the process required to make dehydrated vegetables. The moisture of the fresh product must be removed without extracting the nutritious juices or destroying the food value or flavor. After the vegetables have been peeled and sliced or cubed, they are blanched, in order that they may retain their starch components. They are then placed on trays in huge kilns, through which heated air is blown until only the small required amount of moisture is retained. The product is then packed in hermetically sealed cans.

Dehydrated vegetables occupied a prominent place in the soldier's menu in France. Reports from overseas by inspectors of the Subsistence Division indicated that dehydrated vegetables were quite satisfactory. The Surgeon General's office approved their use. However, when fresh vegetables could be purchased in foreign markets they were used in preference. The use of dehydrated vegetables saved two-thirds of the cargo space which would have been required for fresh vegetables. Their use came at the time when the cargo space was as valuable as life itself, and it enabled men and munitions to be transported sooner than would otherwise have been possible. Dehydrated vegetables were also found especially adapted for use at the front when food was being carried forward from the railheads to the trench kitchens under shell fire.

The emergency ration and its production make another interesting story. Designed to be used only in dire extremity, the ration was packed in small cans to be carried in the soldier's pocket, usually the upper left-hand jacket pocket. This ration corresponded to the starvation ration of the Allies. Its components were adopted after experiments at the battle front and after consultations with food experts. It represented the greatest amount of food that could be concentrated in the smallest compass.

The complete ration consisted of three cakes of a mixture of beef and ground cooked wheat, each cake weighing three

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ounces; three one-ounce cakes of chocolate; three-quarters of an ounce of fine salt; and one dram of black pepper. From the beef the preparation process removed all fat, sinew, and white fibrous tissue. The meat was then heated and all its moisture evaporated so skillfully that no flavor was lost. The wheat or bread component of the cake was prepared by removing the chaff from cooked wheat which had been kiln-dried, parched, and then ground to a coarse powder. The meat and bread were compounded together, about two parts of bread to each part of meat, making a perfectly homogeneous cake. The chocolate of the ration was prepared by combining equal weights of fine chocolate, containing not less than 20 per cent of cocoa butter, and pure sugar, and molding the product into cakes weighing one ounce each. The several components were packed into oval tin cans, which were camouflaged to render them inconspicuous. These cans bore the legend:

> **"U. S. Army Emergency Ration. Not to be opened except by order of an officer, or in extremity."**

Many ways of preparing the emergency ration for eating in the field were found by experiment. The bread-and-meat cake could be eaten dry; or, when boiled in three pints of water, it made a palatable soup; boiled in one pint of water, it produced a thick porridge which could be eaten hot or cold; the cold porridge could be sliced and fried when circumstances permitted. The chocolate could be eaten as candy or made into a drink by placing the chocolate in a tin cup of hot water.

The gas attacks in the trenches made it necessary that the soldiers' food be packed in containers impervious to mustard gas poison, for mustard gas, when swallowed, attacks the intestines. The first call for such a ration came during October, 1917, and it called for the shipment of 100,000 sealed rations a month for twenty months. The food was to be packed in hermetically sealed galvanized iron containers, holding twenty-five rations each. The contents of each can consisted of twenty-five pounds of meat in one-pound cans, twenty-five pounds of hard bread in eight-ounce cans, and twenty-five rations each of

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soluble coffee, sugar, and salt. Tobacco and cigarettes were added for the comfort of the men. The addition of tobacco and cigarettes was accidental. It was found necessary at first to fill the surplus space in the containers with excelsior. The office force of a large corporation learned of this fact and got permission to fill the empty space in some of the containers with tobacco. The Subsistence Division thought so well of the idea that orders were issued for the tobacco ration to be placed in all reserve ration containers.

One of the most difficult elements in supplying the reserve ration was the securing of tin cans for hard bread. These, because of their unusual size and shape, could be manufactured only after new can-making machines had been designed. The demand for such cans exceeded 10,000,000. Within a comparatively short time, however, hard bread in cans for special reserve rations was being produced on a large scale, and the overseas requirements were filled.

Next the manufacture of the necessary galvanized containers and crates was contracted for. A packing plant was then designed to pack the components into the containers, which was an intricate operation in itself, the number of rations being so great. This plant was so contrived that the parts of the packing material came in at one end of the plant, and the hard bread, canned corned-beef hash, canned roast beef, and canned corned beef, canned fish, coffee, sugar, salt, and can openers were packed into the galvanized containers as they traveled on a conveyor belt, until all the components had been included.

Only the best of army purchases were put into the reserve ration. A study was made to ascertain who were the best packers of the various commodities, and their products were used exclusively. Everyone connected with the packing knew the purpose of the ration. It was to be used only when the trenches were under the heaviest fire—when hot food could not be carried forward, and when the men were most in need of good food. The reserve ration became, as a result of this rigor, the quality ration of the Army. After the packing was complete, the cans were hermetically sealed by solder and camouflaged

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with olive-drab paint. The container of the ration, when packed, was so buoyant that it was a potential life raft; it would support two men in the water.

It was also necessary to feed our men in German prison camps. A ration for American prisoners was prepared by the Subsistence Division of the Quartermaster Corps, in conjunction with the Food and Nutrition Division of the Surgeon General's office. This ration was distributed by the American Red Cross from Denmark and Switzerland. Individual packages, each containing sufficient food to supply one man, were sent to the prison camps each week. The chief components of the package were corned beef and salmon (with an occasional substitution of corned-beef hash and canned roast beef), hard dry bread, dry beans, rice, baked beans, and fresh potatoes (where possible). Prunes, jam, apples, peaches, coffee, sugar, evaporated milk, vinegar, salt, pepper, and pickles were also supplied. Potatoes and onions were procured, when possible, in Ireland, France, and Italy; otherwise, dehydrated potatoes and onions were used. Special food was sent for the invalid prisoners, their ration containing potted chicken, crackers, concentrated soup, dehydrated spinach, creamed oatmeal, cornstarch pudding, sweet chocolate, extract of beef, soluble coffee, and like items. There were several substitutes for each item mentioned, among the substitutes being dried eggs, potted veal, cheese, peanut butter, dried apricots, honey, corn meal, gelatin, malted milk powder, bouillon cubes, apples, oranges, lemons, cocoa, and tea.

When the American troops entered the trenches it was found impracticable to use the ordinary roasted and ground coffee. Its preparation required too much fire, the smoke of which made a target for the enemy. Experiments were made with soluble coffee with the object of guaranteeing a warm stimulant in the trenches. It was found necessary to give hot drinks to the men before they went over the top and after they had undergone periods of exposure. The British and French troops were supplied with brandy, wine, or rum on such occasions. But issues of intoxicants to soldiers were contrary to the Ameri-

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can policy, and quantities of soluble coffee were substituted. Solidified alcohol was supplied, so that the coffee could be served hot.

The soluble-coffee industry was in its infancy in the United States. So great was the demand for soluble coffee from the overseas forces that the calls were for over thirty times the prewar production. A cablegram received in October informed us that after January 1, 1919, the troops would require 25,000 pounds of coffee each day in addition to the amounts packed in the trench rations, these latter quantities alone amounting to 12,000 pounds daily. Allowance was also made for possible sinkings of 5,000 pounds daily, making a total of 42,000 pounds necessary to meet the daily requirements of the American Expeditionary Forces. The entire American output of soluble coffee was taken over for the Army, but this amounted to only 6,000 pounds daily. A number of manufacturers of other food products were induced to turn their entire plants into soluble-coffee factories. The greatest difficulty was incurred in securing the necessary equipment for these new plants. There was but one company in the entire United States which made the revolving bronze drums essential to the manufacturing process. This company ran its plant seven days a week, with three shifts daily, to produce the necessary materials. The metals which went into these drums were vital in the manufacture of other munitions, but it was even more important that men in the front lines be given hot drinks when tired and worn from long fighting and exposure. The signing of the armistice saw the difficulties of supplying soluble coffee well-nigh overcome. The Subsistence Division had won one of its hardest fights. The coöperation of American manufacturers had made the achievement possible.

The problem of supplying good coffee to the troops was a difficult one. To make good coffee for a unit as large as a company is not easy for the average cook. To guarantee that good coffee would always be available, the Subsistence Division made one of its most radical changes in handling supplies. This change was so complete that, whereas the Army had

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formerly been served with coffee from three to six months out of the roasters, it came to be supplied with coffee freshly roasted every day. At the beginning of the war, coffee was purchased, ready roasted and ground, from competitive dealers. It was then held in New York for about thirty days before being shipped overseas, the transportation requiring thirty days more. Received in France, the coffee was often kept for ninety days before it was distributed to the troops. In addition, a thirty days' supply must be kept on hand; so that the coffee was six months old by the time it was used. When it finally reached the men it had lost half its value as a stimulant and had greatly deteriorated in flavor, being often in a crumbly condition. Muddy coffee on the mess tables resulted.

The only way for the troops to secure fresh coffee was for us to send over the green product for roasting as it was needed. Buildings were erected to house coffee-roasting machinery at home and abroad; men were trained as quickly as possible in the process of coffee-roasting, and sent out to take charge of the plants. In a relatively short time sixteen plants were in full operation in France, and an increasing number at home. Eventually all the coffee used in France was shipped over green and roasted in the plants there. These plants were capable of roasting sufficient coffee to take care of 3,000,000 men, at a considerably lower cost to the Government than under the old system.

The Expeditionary Forces, as we have noted elsewhere, organized a purchasing office in Paris. The purpose of this office was to save tonnage space by securing as many products as possible in Europe. Its scope covered all classes of supplies, but a large section was devoted to subsistence. Candy, hard bread, and macaroni factories under the direction of the Quartermaster Corps were built or secured from the French Government. Large quantities of beans, fresh potatoes, onions, coffee, rice, salt, and vinegar were secured from European markets. Many thousands of tons of foodstuffs were purchased and manufactured in Europe for our Army, every ton representing space on ships saved for additional men and munitions.

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Overseas purchases were generally discontinued after the signing of the armistice, as the Director of Purchase and Storage and the Commander of the Expeditionary Forces were firm for the policy of favoring American manufacturers wherever possible.

To reduce tonnage still further, extensive experiments were made in the packing of beef for overseas consumption. All bones, surplus fats, and waste portions were removed. The remainder, all edible, was pressed into 100-pound molds and frozen. The initial shipment was composed of sixteen carloads of boneless beef. The meat arrived in France in splendid condition, and was carefully watched from its arrival at the ports in France to its consumption in the front-line trenches. Officers, mess sergeants, and cooks were enthusiastic over the boneless beef; it took much less time to prepare, and therefore saved a great deal of labor. The men were gratified because the inferior portions of the beef were not included, and much better meat resulted for the mess. After the success of this experimental shipment, as much boneless beef as possible was sent to France. Trouble was encountered in securing the skilled butchers to bone the great quantities needed, but this shortage was largely overcome.

No means was discovered so effective for reducing tonnage as boning beef, dehydrating vegetables, and purchasing foods in France, but in many of the smaller items there were stories just as interesting. Efforts to save tonnage brought about the reduction of moisture in soap. While the Subsistence Division was securing toilet paper it found that the entire supply for the Expeditionary Forces could be stored in the waste space of army rolling field kitchens. A special formula for vinegar was devised, and double-strength vinegar was shipped. This, when mixed with an equal quantity of water in France, was a good product.

The saving of space in the transportation of subsistence stores makes a long story in itself. Just so much tonnage was allotted to food each month, and the ablest men in the food industry spent much time in working out how the maximum

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of necessaries and luxuries in foodstuffs could be sent in the minimum of space.

The Subsistence Division looked after, not only the working fighter, but the playing fighter as well. The American soldier is fond of candy, tobacco, and chewing gum. The supply of these commodities brought much pleasure to the troops. Long lines of men waiting for free candy and tobacco in France, men who had just come from the front, formed one of the interesting sights of the war. Tobacco established its claim to a recognized place in the soldier's life. Probably 95 per cent of the soldiers of the American Expeditionary Forces used it in one form or another. In May of 1918 it was decided to adopt the practice of the Allies: namely, to allow each soldier a certain daily amount of tobacco. This unusual innovation was the official recognition of tobacco as a necessity for men in active service. To men enduring physical hardships, obliged in times of battle to live without the comforts and often even the necessaries of life, tobacco fills a need which nothing else can satisfy. The daily ration of four-tenths of an ounce was given to every man overseas who desired it. The soldier had the choice of cigarettes, smoking tobacco, and chewing tobacco. If he chose smoking tobacco, he received cigarette papers with it. In addition, the men could buy in unlimited quantities, at any army or other canteen, the most popular brands of cigars and cigarettes.

The Subsistence Division purchased for overseas shipment a monthly average of 20,000,000 cigars and 425,000,000 cigarettes. Abundant tobacco was on hand in the commissaries overseas, and the soldier could buy it at actual cost. There was no profit or tax added on any tobacco shipped to France, and it was sold at retail to the troops at a cost lower than the price paid by the biggest wholesalers in the United States. The plan for the purchase of cigars and cigarettes was to divide the contracts among the most popular brands in the proportions in which those brands are sold in this country.

Candy, in the days of the old Army, had been considered a luxury. The war with Germany witnessed a change. The old

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popularity of chewing tobacco waned; that of candy increased. Approximately 300,000 pounds of candy represented the monthly purchases during the early period of the war. This amount included both home and overseas consumption. Demands from overseas grew steadily. The soldier far from home and from his customary amusements could not be considered an ordinary individual living according to his own inclinations, and candy became more and more sought after. As the demand increased, the Quartermaster Department came to recognize the need of systematic selection and purchase.

The first purchases were made from offerings of manufacturers without any particular standard, 40 per cent being assorted chocolates, 30 per cent assorted stick candy, and 30 per cent lemon drops. A standard was developed through the steady work of confectionery experts. This standard offered no opportunities for deception, and it guaranteed candy made from pure sugar and the best of other materials. The specifications furnished to all bidders covered both the raw materials and the methods of manufacture, packing, and casing. Specifications were adopted after many conferences with the leading manufacturers of the country. These men coöperated in the work by giving their best suggestions and often their trade secrets.

Huge purchases of candy were made during the days when sugar was scarcest in the United States. The Food Administration was convinced that the Army should have all the candy it wanted, and sufficient quantities of sugar were allotted for the purpose. From 300,000 pounds monthly the candy purchases increased till they equaled 1,373,300 pounds in November, 1918, the highest amount purchased up to that time. In December, 1918, an innovation was adopted, consisting of giving the troops a regular monthly ration of candy. The candy which had been shipped every month for sale in the various canteens had always been quickly disposed of. Many men did not get the opportunity to make purchases. The ration plan, however, assured each man a pound and a half a month, without exception. It took 3,495,000 pounds to provide each soldier

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overseas with his allotted portion in the first month of the ration system.

In December, 1918, the Subsistence Division took over the purchase of all candy for the various organizations conducting canteens for our troops. The purchases for that month totaled 10,137,000 pounds, all of which was shipped overseas. It was the largest exportation of candy on record. The candy purchased for the canteens, commissaries, and other agencies was manufactured by the best-known candy firms in the country. A portion of the candy consumed overseas was manufactured in France. This French supply was discontinued January 15, 1919, and thereafter all requirements were shipped over from the United States. The candy was sold to the men at just half the price it would have cost individuals here. After December, 1918, 50,000 pounds were furnished each month for sales purposes for every 25,000 men in France. Up to February 1, 1919, 21,000,000 pounds of candy had been sent across. The demand for candy jumped skyward after the signing of the armistice, the men then having more time on their hands in which to enjoy luxuries. Tobacco demands likewise increased.

The suffering sweet tooth of the Yank was not appeased by candy alone. The third of a billion pounds of sugar bought for the Army represented a tremendous number of cakes, tarts, pies, and custards. An old soldier recently stated that the ice cream eaten by the Army during the war would start a new ocean. The serious shortage of sugar which at one time threatened to reduce sweets to an irreducible minimum on the civilian bill of fare did not interfere with the soldier's ration, which continued to be six pounds monthly in this country and about nine pounds overseas. The ration for the civilian population was reduced to two pounds monthly. Army officers were placed on the same status as the civilian population and were allowed to purchase only the amount stipulated for civilians for use in their homes. Up to the signing of the armistice the total amount of granulated, cut, and powdered sugar purchased by the Subsistence Division equaled 342,745,862 pounds and cost

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$28,465,050. Of this amount, the greater portion was shipped to the troops in France.

A close companion in popularity to candy and tobacco was the typical American product, chewing gum. This confection was found of great value on the march as a substitute for water. Its importance is shown by the vast amount sent overseas. A total of 3,500,000 packages represents the overseas shipment in January, 1919. The shipment for February was 3,200,000 packages. The winter consumption of gum was heavier than that of summer, the average monthly supply being only 1,500,000 packages during the summer of 1918. Chewing gum came to be considered a necessity by the men in France; it was found to be an invaluable aid to keeping up their spirits in the midst of hardships.

Every complaint against meals served in the Army, on reaching the attention of the Subsistence Division, was investigated. The investigations were made in conjunction with the Inspector General's Department of the Army. Where complaints were justified, remedial action was taken. A study of the complaints revealed that the most dissatisfaction was among new troops, who, when first separated from the luxuries of home, wrote of their adventures at the mess table, enlarging any lack of home comforts into stories of privation. The more solid food, however, soon became popular, as the hard work in training gave an appetite for sustaining rather than for the more fancy dishes.

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CHAPTER XXX

CLOTHING AND EQUIPAGE

THE Army raised against Germany had to have stout shoes for its feet. It required warm uniforms and overcoats and good socks and underwear. It had to have heavy blankets for its beds. The men needed raincoats and rubber boots for wet and muddy weather. Tentage was required—pup tents for the front and large tents and flies at the camps. Belts and bandoleers of cotton webbing added to the soldier's efficiency as a rifleman or machine gunner.

To procure these and other supplies for an American Army that eventually reached the strength of 3,750,000 men required the best brains in the textile, rubber fabric, and leather goods industries. From the countingrooms of these industries, from their laboratories and factories, the needs of the Government called to Washington several hundred men and put them into American officers' uniforms. Eventually the various agencies of the War Department which purchased these supplies were centralized in a single division known as the Clothing and Equipage Division of the Office of the Director of Purchase and Storage, which in turn was part of the Division of Purchase, Storage, and Traffic. The total cost of this necessary equipment of textiles and leather and rubber goods was approximately $2,100,000,000. Of the enormous sum of money appropriated for the so-called quartermaster activities, a full one-quarter went for clothing and equipage of this sort.

The group who handled this enormous manufacturing effort not only conducted one of the biggest undertakings of the war, but did it in a way to command the admiration of those who knew the story of what was going on. The division turned scientific attention—and that means the attention of real scientists—to the proper construction of all sorts of articles.

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It designed new styles of soldiers' clothing, adapted in every curve and line to the service in France. It standardized dyes and made studies of protective coloring. It produced highly specialized shoes. It saved millions of dollars by the scientific study of specifications of various articles. It educated manufacturers in the production of articles strange to their experience, and in some instances developed entirely new industries. At one time it constituted within itself the entire wool trade of the United States, since it had optioned every pound of wool in sight and had its agents out gathering up the excess wool of the earth. It was a shipmaster, an employer of men, a reformer in labor conditions, and an inventor and originator of new products.

The organization was important, not only for the size of its business, but also because it dealt more intimately with the individual soldier than any other production branch of the Government, with the possible exception of the branch which fed him. It might seem to be a fairly easy undertaking to buy clothing for a soldier, and to buy his tent, and the bedclothing that kept him warm in active service or when he was a patient in a military hospital. But it was not a simple task. None of these articles was standard for civilian use, in material, color, or pattern. Everything had to be made to order. The ordinary factory could begin work on contracts for these supplies, not on a minute's notice, but usually only after special and sometimes costly preparation. And as the Army grew in size it had to have large quantities of special clothing. Cooks needed cotton aprons, and blacksmiths, leather ones. Linemen had to have special gloves; hospital orderlies and waiters at messes required white duck suits; motorcyclists needed hoods; laborers, overalls; and firemen, helmets. There were special garments for aviators. We began capturing prisoners, and they had to have special uniforms. Convalescents at hospitals needed special suits. The women nurses of the Army were supplied with uniforms—something entirely outside previous army experience.

The Government was something more than the designer and

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manufacturer of these goods, drawing the specifications, placing the orders, and then teaching the processes of manufacture in the thousands of factories which had virtually become government plants. The clothing and equipage organization had to go further back and become the actual procurer of the raw materials; and this phase of its work eventually became one of the largest and most spectacular and romantic elements of the whole undertaking. In addition to procuring the raw cotton and the raw wool and the hides, the Government had to go into the manufacture of cloth and the tanning of leather, to supply these commodities to the manufacturers of the finished articles. The Government went into a raw materials market which was already glutted with orders from the Allied governments and from domestic consumption. It went into this market at first without money, for funds on the scale demanded were not available between March 4, 1917, and June 15 of the same year; and it had to buy on credit and secure the commodities in the face of cash bidding for them.

Nevertheless, the whole enormous undertaking was successfully carried through. Except in rare instances, the American soldier never lacked for necessary supplies of the sorts mentioned. The organization which handled the work originally consisted of six officers and twenty-five clerks. When the armistice was signed this great purchasing and manufacturing agency had an enrollment of 1,693 persons.

Wool was the most important of the raw materials to be procured, since wool entered into the composition of more items than any other substance. Uniforms, overcoats, underwear, socks, breeches, shirts, and many other articles had to be made entirely or partially of wool. The purchases of woolen breeches alone during the war period amounted to 13,176,000 pairs. On September 10, 1918, the wool experts of the Army estimated the nation's total needs for wool up to June 30, 1919. The War Department, it was found, would require during this time 246,000,000 pounds of clean wool; the allotment to civilian needs was but 15,000,000 pounds. In other words, the war demands were to absorb practically the entire

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supply of wool; civilians were to be forced to do without it almost entirely. Soon after the declaration of war the Quartermaster Corps estimated that it would require about 100,000,000 pounds of scoured wool to meet the initial demands of the Army in 1917. A meeting was called of the principal wool dealers of the United States, most of them from Boston, and a quick inventory was taken of the available wool supplies, not only in the United States, but on order from foreign countries. It was found that there was in sight 78,000,000 pounds of greasy wool, which, after being scoured, would produce 35,000,000 pounds of wool of the quality needed. This was barely one-third of the Army's demand alone. It should be noted, however, that this inventory was taken just before the annual American clip, which would be finished by the end of July. To ensure that the Government should secure every pound of wool in sight, options were promptly obtained on all wool in American warehouses or on the sea, and speculation in the prices of the domestic clip for 1917 was thus headed off by the entry of the Government itself into the raw-wool business. The prices were fixed for the 1917 clip as of July 31. A year later the Clothing and Equipage Division had become the entire wool trade of the United States. There was no wool market again, and no public sale of wool, until after the armistice was signed.

To handle this enormous undertaking the division appointed a wool administrator to buy wool, a wool-purchasing Quartermaster to pay for it, and a wool distributor to sell it to the government contractors. The Government's wool headquarters was in Boston, with branches at Philadelphia, Chicago, St. Louis, San Francisco, and Seattle. This organization arranged to procure the whole 1917 clip, if needed, took over all wool destined for the United States under import licenses, and sent its agents to foreign markets.

The largest of the foreign markets practically available from the standpoint of distance was the Argentine in South America. Australia and New Zealand were, of course, enormous markets, but the dearth of shipping made it impossible

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to spare many bottoms for the long voyage into the Antipodes. As a matter of fact, when the fighting ceased the whole world was suffering for wool, except Australia and New Zealand. America was short of wool, France had practically none, there was little in England; but Australia and New Zealand had the staggering surplus of 1,000,000,000 pounds. This was due to the fact that there had been no shipping available to bring this wool to America or Europe. The Government's wool administrator secured such Australian and New Zealand wool as he could; but he had to rely principally on sailing vessels, which could not, under the most favorable conditions, go to Australia and back again in less than seven months, while nine or ten months were more often required. A quick sailing voyage to Argentina and back required five months. Nevertheless,—and this was particularly true in the early fall of 1918, when preparations were being made for the equipment of the Army in 1919,—every effort was made to secure foreign wool. A South American wool-buying commission was formed and sent to Buenos Aires, arriving there October 30, 1918. By that time, however, the end of the war was in sight, and the commission never opened up its Argentine headquarters.

The Government conducted its raw-wool business on the system of a great department store. Headquarters were established in Boston, where the wool distributors kept samples of almost every kind of wool produced on earth, these samples representing stocks on hand in the various government warehouses in Boston and elsewhere. Charles J. Nichols, a member of a large Boston wool firm, was the wool administrator, and E. W. Brigham was wool distributor. Prices were fixed, and the manufacturers bought from the samples. Carpet wool was sold at an office in Philadelphia. The wool administrator did a business that averaged $2,500,000 a day during his incumbency, his total purchases amounting to about 722,000,000 pounds of wool.

At first the supply of the better grades of wool seemed to be adequate to the Army's demands. Later, however, changes were made in the specifications for various cloths, uniform

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cloth being increased from 16 to 20 ounces in weight, overcoating from 30 to 32 ounces, shirting flannel from 8½ to 9½ ounces, and blankets from 3 to 4 pounds. These increases made it necessary for the Army to use grades of wool previously made only into coarse materials like carpet. The lower grades of wool were blended with the finer grades to provide the necessary weight and warmth, even at the expense of fineness of texture and appearance. This action explains why, at the end of the period of hostilities, some of the American soldiers' uniforms looked rough and uneven in color. But the necessary cloth was provided, and it was warm.

The Government saved every ounce of wool it possibly could save. More economical patterns and layouts for the cutting of uniforms were designed in Washington and furnished to the manufacturers. The American soldier's uniform did not meet the approval of officers of the American Expeditionary Forces as to style, after the officers had become used to seeing the smartly dressed troops of Europe. Accordingly, after General Pershing had recommended a better-appearing uniform, a new one was designed, incidentally with an eye to saving cloth. The coat of the uniform—formerly called the blouse, a designation now obsolete—was cut with new lines, making it slimmer without sacrifice of warmth or comfort. The patch pockets of the original blouse were usually unsightly bulges when the soldiers filled them with articles. On the new coat the patch pocket was retained only in appearance, the pocket actually being on the inside.

It is not known to most Americans that the breeches, which had been typical of the American service uniform for many years, were abandoned late in the war in favor of long trousers. This change was also due to studies made by the army clothing experts. The soldiers themselves were not enamored of breeches, since they had to be either laced or buttoned below the knee, a process which took time always, and seemed to take more when a man was in a hurry. The laces sometimes chafed the leg under the leggins. Then, too, it was often impossible to remove the breeches from soldiers wounded in

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the legs, except by cutting the cloth. Long trousers did away with all these objections and had the added virtue of being warmer than the breeches.

The overcoat, too, was redesigned, following General Pershing's recommendations, the stock overcoat being too long to be worn in the trenches. A knee-length garment was provided which was much smarter than the older coat.

The redesigning of the overcoat and the uniform (although the new uniform never appeared in the field) accomplished numerous economies. Merely by the elimination of lacings, eyelets, tape, and stays, the new trousers cost 95.25 cents less than a pair of army breeches. By July 1, 1919, this change in design would have saved the Government $16,988,440 in orders for trousers already placed or in sight. The change in overcoat styles saved 62 cents a garment, or a total saving to July 1, 1919, estimated at $897,140. The service coat, made by redesigning the blouse, saved the Government $1.598 on each garment, or an estimated saving of $4,977,770 to July 1, 1919.

These modifications accomplished, not only a financial saving, but, what was more important, a saving in the consumption of the raw material, wool. The Government could always raise more money; but if the wool supply were exhausted, all the money on earth could not buy more. A more economical cutting pattern saved twenty-three one-hundredths of a yard of cloth in the manufacture of every pair of trousers. This resulted in the total saving of 2,300,000 yards of woolen cloth. Part of the facings of the service coats and overcoats were eliminated without sacrificing warmth or serviceability, and cheaper cotton linings were substituted. Another important cloth economy came when the army designers cut off the right-hand pocket of the O. D. shirt, on the ground that this pocket was seldom used. The designers also substituted an oblong elbow patch on the army shirt for the circular patch formerly specified. This substitution was not an economy in cloth, but the original circular patch, put on the sleeve to reinforce it at the point of greatest wear, actually resulted in reducing or

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shortening the life of the garment by tearing loose at the stitches, a fault which the oblong patch overcame.

In the earlier contracts the garment makers were stimulated to save wool by being allowed a percentage of the cost of yardage saved. Each contractor, too, was permitted to sell his own clippings. But as the Government obtained a more scientific grasp of the clothing problem and produced pattern layouts which utilized the maximum percentages of the cloth, the issues of cloth to the garment makers were calculated more closely. Thereafter the contractors received no reimbursement for cloth savings, and the Government itself took all the clippings. These clippings were shipped to a base sorting plant at New York, where they were baled and shipped out to mills to be used as reworked wool in blankets and other articles. The clippings were sorted at a cost of 1.7 cents a pound and sold at an average price of 23 cents a pound, the total sales bringing in to the Government $5,500,000.

The history of the Government's wool enterprise during the war illustrates how hard it was to check the momentum of the whole war production undertaking, once it had attained full speed. A week before the armistice was signed the wool stocks looked small, and shortages plainly existed such as to cause anxiety for the executives in Washington. That was because we were thinking in terms of the consumption made familiar by the terrific destruction of war. A week later the same stocks looked overwhelming in size, and the shortages had become enormous surpluses. It had been a constant worry to procure a sufficient quantity of blankets; yet, as soon as the armistice was signed, we had on hand a forty-seven months' supply of blankets for 1,000,000 men in the United States and 2,400,000 men overseas. As soon as the German plenipotentiaries affixed their signatures to the armistice agreement, an apparently small stock of marching shoes turned into a four-year supply for 3,400,000 soldiers at home and abroad. On November 1, 1918, the Clothing and Equipage Division had on hand a reserve stock of goods valued at $811,000,000.

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The entire woolen industry, from the handlers of raw wool to the textile mills, worked splendidly with the Government. At all times there was plenty of available machinery to make all the cloth for which wool could be furnished. Mills which found no government use for their regular business output went heartily to work to make something else that the Government would need. The Government's uses for carpet, for instance, were practically negligible; and the carpet mills, many of them, swung their entire production to army blankets and army duck. Blankets, in fact, were one of the largest items. The total purchases brought to the government warehouses about 22,000,000 blankets, at a total cost of over $145,000,000.

Melton cloth for overcoats and uniforms consumed an enormous quantity of wool. The total purchases of melton amounted to more than 100,000,000 yards, or enough to stretch twice around the world at the equator, with a strip left over long enough to reach from New York across Germany and Russia and into Siberia. The total quantity of raw wool bought by the Government up to December 14, 1918, cost over $504,000,000.

After the Government had secured the wool and various types of cloth, there still remained the task of making this cloth into uniforms. The usual method was for the Government to furnish the materials and to pay the contractor his cost of manufacturing.

All army clothing was made up according to the so-called tariff sizes. The average coat for a man is a 38 or 40, and experience shows how many men in a given number will need this average. But there were always exceptions. One camp sent in a special order for forty-six overcoats for "fats." Through a scientific study of the problem, notable reforms in the matter of fitting soldiers were brought about. When the men were coming in greatest numbers from civilian life to the training camps, they were often put to great inconvenience in securing proper clothing. Each man would ask for such sizes as he thought were correct, but it often happened that the garments

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supplied to him did not fit him, and he thereafter spent some hours or even days swapping garments with other recruits, until he eventually acquired an outfit somewhere near his size. Then, too, there was confusion in the way the articles were supplied to the men, who sometimes had to stand in line all day long, awaiting their turn at the issue windows.

The matter of fitting was satisfactorily solved by adopting the so-called foolproof size labels. The labels originally used were merely paper tags pinned to the garments, and in handling of garments by men unfamiliar with the fitting of ready-made clothing, mistakes often resulted. Like civilian clothing, all army clothing was divided into four classes, known as "longs," "shorts," "stouts," and "regulars." A garment of any size would come in each of these four classes. Each label was marked with a diagonal colored stripe to indicate the general characteristic of the garment to which it was attached. Green meant a "short," red indicated a "long," and yellow showed the garment to be a "stout." The soldier was pretty sure to remember the color of the stripe attached to the garment that fitted him. If he were a green striper, he would refuse to accept anything that did not bear a green stripe on its ticket.

Before hostilities ceased, a system had been introduced which provided a more scientific issue of clothing to recruits. Under this system the recruit would enter the supply building at one end and there, in a special room, strip himself of his civilian clothing, He would thereupon enter the mill as naked as the Lord made him. He would stop first at the underwear counter, where he would procure and don garments that fitted him; then he would pass on to the hosiery counter. Thus he would progress down the line, eventually emerging from the other end of the building, a fully dressed American soldier. The process reminds one of the progress of an automobile through the Ford factory.

It required the services of some 4,000 inspectors to supervise the garment-making in thousands of shops scattered throughout the country. This inspection also scrutinized the

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character of the shops which took contracts, and the Government was sometimes hard put to it to prevent child-labor and sweat-shop production in the work.

At one time there came a rush order from France to supply several hundred thousand mackinaws. An officer who was familiar with mackinaws was sent out from Washington to buy them from goods in stock. He accomplished his mission in ten days, literally baring the shelves of the United States of these garments, his purchases including the extensive quantities of mackinaws held by mail-order houses in Chicago.

It was always a problem in clothing the Army to find olive-drab dyes that were fast in color. The first dyes used were apt to fade quickly. A certain dye of the proper color was found on test to have the peculiar characteristic of being visible at a distance. As the new American synthetic dye industry expanded and processes were perfected, the officers of the Clothing and Equipage Division were able to coöperate with the American dye makers to produce satisfactory dyes. The olive-drab dye used in dyeing coats and trousers seemed to withstand the sun and rain, whereas that used in coloring the leggins proved to be extraordinarily fugitive. It seemed to be impossible to produce a dye that would hold its shade in leggins. The experts working on the dye problem had expended a good deal of valuable energy in worry and had grown a few gray hairs in their heads over the failure of leggin dyes, when they discovered the true cause of the fading. The men were deliberately bleaching out their leggins, usually by using salt solutions on them, since any leggin but a faded one indicated that the soldier who wore it was a rookie and a greenhorn.

The materials which went into the manufacture of clothing came from various sections of the country, because the several garment industries had grown up around defined centers. For instance, melton cloth came generally from the Boston district. Linings were supplied from Atlanta, buttons from Philadelphia, and duck from Chicago. This geographic distribution of supplies simplified the Government's problem of supplying materials to the various contractors. It was possible to supply

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materials on short notice to any garment-making district. At one time Chicago wired that, unless 500,000 yards of flannel shirting were supplied immediately, hundreds of shirt factories in Chicago and the Chicago district would have to close down. Accordingly, a special freight train was loaded with shirting in the East and started for Chicago on a special movement in charge of a "live tracer"—that is, an officer who saw that the train was put through to its destination. The train arrived in Chicago on the second day after the order was received, so rapidly had the goods been procured and loaded.

In addition to the regular uniforms for the men, almost half a million articles of clothing for officers were also bought by the Government.

The Quartermaster Department went into an entirely new field when it bought uniforms for the women nurses of the Army. There were a Norfolk suit which cost about $30, a cotton uniform that cost about $3, an overcoat costing nearly $28, and then there were waists made from navy blue silk and from white cotton, and hats.

Before leaving the subject of clothing, it is interesting to refer again to the clothing furnished for prisoners of war taken by our troops. This was not manufactured for the purpose. Uniforms discarded by our own men were reclaimed and dyed a special shade of green. Over 50,000 of these garments were prepared at an average cost of less than thirty cents a garment. It had been the original intention to make a special prisoner's uniform, striped in resemblance to the prison suits worn in American penitentiaries.

Another interesting development in the manufacture of army clothing was the production of a special uniform for expeditionary troops sent to Russia. This uniform was so warm that it could well have served as the equipment for an Arctic exploration party. The determination to send an expedition to Russia was made suddenly by the Government, and the decision brought with it the problem of producing in a jiffy an equipment of garments not only expensive in themselves, but of a sort unknown to the American garment trade. An agent

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for the division in New York at once bought on the New York market large quantities of muskrat, wolf, and marmot fur. Other agents were sent into our own Northwest and to Canada to pick up such suitable garments as those markets afforded. The Siberian equipment as specified by the commanders of the expedition called for fur caps, fur mittens, and fur overcoats, mucklucks, moccasins, felt shoes, fur parkas, and underwear for 15,000 or more men. The order for the equipment came in the latter part of August, 1918, so that only the fastest kind of work could produce the garments in time to catch the last steamer going into the northern Russian and Siberian ports before the ice closed navigation for the season. Therefore, whenever the articles specified could not be procured on time, suitable substitutes were provided. The specifications called for 80-per-cent-wool underwear. Underwear with that percentage of wool could not be provided, but underwear of equal weight was substituted. Where fur-lined garments were unobtainable, fur-trimmed ones were procured. The specifications called for buffalo coats. The division sent a man to the north woods country of Minnesota and Wisconsin, and there in the supply cities he bought, as a substitute, sheep-lined coats with moleskin or duck shells. These coats were the sort used by woodsmen and Alaskan miners and explorers. There being no time to procure mucklucks, moccasins, and felt shoes, an agent of the division was sent into Canada to buy shoe pacs (or lumbermen's boots) and lumbermen's knee-length socks. The total cost of the outfit was more than $100 a man.

It was impossible to find any substitute for the Alaskan parka. A parka is a sort of overshirt, wind proof and waterproof, and hooded, to be worn over the overcoat and cap of the uniform. Consequently it was necessary to produce the parkas in this country, although our garment makers were entirely unfamiliar with such manufacture. The work was undertaken by the International Duplex Coat Company, at 114 Fifth Avenue, New York. It was necessary from the start, in turning out this order, that the employees of this plant work overtime. In order to speed the production the principal mem-

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Photo by Signal Corps

OUTFIT WORN BY AMERICAN TROOPS IN SIBERIA

Photo from Quartermaster Department

RECLAIMED ARMY SHOES

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Photo from Quartermaster Department

MAKING OVERSEAS CAPS

Photo from Quartermaster Department

IN A UNIFORM FACTORY

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ber of this firm himself took his place at the bench and worked almost day and night in cutting out garments.

The day drew closer and closer when the shipment would have to start across the country if it were to catch the last boat from San Francisco. On the home stretch of the race the entire working force of the plant went thirty-six hours, stopping only for meals. The last stitch was taken at 1.30 o'clock in the morning. The garments were then piled upon auto trucks to be rushed to the baling plant in Brooklyn. One of the loaded trucks developed engine trouble and stopped in the middle of a bridge across the East River. The officer in charge thereupon commandeered every automobile that came along, piled them all full of parkas, and sent them to the baling plant. The entire shipment was aboard the train less than one hour before its starting time.

It was not only necessary for the Government to furnish cloth for the uniforms, shirts, and other articles, but it had to supply the fittings and findings as well—such requisites as linings, tape, buttons, and hooks and eyes. In the calendar year 1918 the purchases amounted to over 46,000,000 yards of cotton lining and 2,500,000 yards of felt lining, worth over $18,000,000. The Government spent over $100,000 for hooks and eyes, $150,000 for tape, $1,250,000 for thread, and practically $3,000,000 for buttons.

When it was found that the standard specifications for army uniform buttons favored a certain class of manufacturers and excluded many others, new specifications were drawn so as to make it possible for every button manufacturer in the country to compete for contracts. An exclusive study was made of new materials for buttons. They had been made of brass or bronze, but because of other war necessities for metals an effort was made to provide a substitute. It was found, too, that metal buttons sometimes resulted in infection of wounds received on the battle field. Substitution of vegetable ivory for metal in buttons was attempted. The Bureau of Standards in Washington tested the taqua, or ivory, nuts from which buttons are made and found them suitable. A vegetable ivory

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button with a shank was developed, although no such ivory button had been known before, and the Government's insigne was stamped on it. General Pershing approved the use of ivory buttons, and thereafter many manufacturers produced millions of gross. Every manufacturer who took button contracts agreed to turn over the ivory nut waste to the Chemical Warfare Service to be used in making charcoal for the gas-absorbing canisters of the gas masks. Most of the buttons were produced by firms in Rochester and Philadelphia. Many concerns made them who had never made buttons before. Manufacturers of electric goods, hardware, billiard balls, celluloid, pearl buttons, and phonograph records turned their plants into ivory-button factories. Enormous quantities of buttons were required. For the army shirts alone the Government needed 216,000,000 buttons in 1918.

Flags constituted another class of goods requiring wool. In all, the division produced 40,000 flags during the war period, most of these being made at the Government's own shop at Philadelphia. It is a grim fact that many of these flags were used to wrap around the bodies of soldiers who died at sea. Thirty million chevrons for noncommissioned officers were also turned out by the Government.

The production of overseas caps for the American Expeditionary Forces was likewise an extensive undertaking. When the requisition for overseas caps came from France, it was not possible to design one here, because of lack of knowledge of what was required. Later a courier bearing a sample cap came to the United States from General Pershing. As soon as this sample was received, a meeting of cap makers was called in New York, which a hundred manufacturers attended. One and all agreed to turn over their factories to the exclusive production of overseas caps until the requirements were met. It took these cap makers only two weeks to turn out the first order. In all, 4,972,000 caps were delivered.

Our experts on this side of the water were not satisfied with the overseas cap. It shrank after being wet, it quickly lost shape, it absorbed much water and did not dry out quickly,

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and it was unattractive in appearance. Also, it did not shade the eyes, and the experience in France showed that the soldiers usually improvised peaks to their caps by sticking their girls' letters between their caps and their foreheads. Moreover, the standard cap was made of 20-ounce melton, a fabric hard to get. But there was plenty of rabbit fur available to make felt caps for an army of 6,000,000 or 7,000,000 men. Accordingly a new felt cap was designed, which did away with the bad features of the melton cap; but this improvement came at the end of the war and was never used.

Not only was wool required for the outer clothing of the Army,—for the uniforms, overcoats, and caps,—but there was also a tremendous war demand for it for the manufacture of such knit goods as undershirts, drawers, stockings, gloves, and puttees. The matter of providing the Army with these necessary articles offered a problem of peculiar difficulty, since, in addition to the ever-threatening shortage of raw wool, there was an actual shortage of machinery in the knitting industry. When it was found that the regular mills could not turn out all the woolen knit goods the Army required, numerous mills which had been turning out specialties exclusively, such as women's underwear or men's union suits, were converted into factories to knit garments according to the army specifications. Some idea of the extent of the Army's demand for this class of goods may be read in the fact that toward the close of hostilities every machine in the United States that could make hosiery at all was knitting socks for the Government.

At one time there was an acute shortage of needles. Germany had previously supplied America with knitting needles. When this source was cut off, we turned to Japan. The Japanese needles proved disappointing: they were not correctly tempered, and frequent breakage caused great loss. At one time it was rumored that there were 10,000,000 knitting needles in Sweden, and the need here was so urgent that several buyers were sent to that country. Their effort was well worth while, for they actually secured a million needles to help relieve the situation here. Meanwhile, American needles were improved

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and American needle makers were pushed to the limit; but until the close of the war there was always an acute shortage of needles for the knitting industry.

It was soon discovered that there was not enough machinery in America to knit one-tenth of the seamless woolen gloves that the soldiers required. We had to adopt a substitute—a glove of knit fabric cut to pattern and sewed up with seams. In actual service this glove did not stand up to the hard usage required of it; consequently there was designed an overglove of canton flannel with the palm cased in leather, this to be worn outside the seamed woolen glove. In the effort to produce gloves which would give longer wear, the so-called ambidextrous glove was designed—a glove so cut that it could be worn comfortably on either hand.

Puttees, the spirally wound leggins that had long been used by the British Army, were unknown articles to American manufacturers when the American Expeditionary Forces adopted them as standard equipment. A puttee of knitted wool was designed, and 6,000,000 of them were ordered in the spring of 1918, these to be preliminary to future orders for 8,000,000. The work required the installation of much new machinery in the textile plants. On November 1, 1918, we had produced all the puttees required by the troops then in France and a surplus of 1,500,000.

In the production of knit goods, economies in the use of material were constantly effected. An original article of equipment for the overseas troops had been a knitted woolen toque, which was a sort of stocking-cap. The toques had cost the Government $1 apiece, and some 1,500,000 of them had been piled up in the quartermaster warehouses before the toque was abandoned as a piece of standard equipment. Later a requisition was received for 400,000 woolen mufflers to be used by drivers of automobiles and motor trucks. According to the specifications these would cost about $3 apiece. Then it was discovered here that the abandoned toques could be sewed together to make mufflers. With this stock in hand, it cost the

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Government only 20 cents each for the mufflers instead of $3, a clear saving of over $1,000,000.

During the war period the Quartermaster Department was the Mecca of inventors, who came bringing real or fancied improvements in many articles of apparel and personal equipment. One brought in a trench shower bath, consisting of a hot-water bag and a hose. He was much chagrined when informed that if this apparatus were set up in the trench there would be no room for soldiers to pass it. In no respect did the inventors have more novel ideas than in the manufacture of underwear. One of them brought in a patented vacuum suit of underwear which acted on the principle of a fireless cooker or thermos bottle to retain the heat of the wearer's body. However, he had failed to consider that not only must cold be kept out, but perspiration must be given a chance to escape. The vacuum underwear would never dry out after a man had become sweaty in it. For that reason it was not adopted. A woman of Iowa invented cootie-proof underclothing by impregnating underwear with vermin-destroying chemicals. The state of Iowa was so interested in her invention that there was a public movement to clothe all Iowa troops in this underwear should the Government fail to adopt it. The underwear was submitted to the Bureau of Entomology (the government agency that deals with bugs), the experts of which tested the invention. They found that the underwear was indeed death to the cootie. But if the chemicals were applied in weak strength they soon evaporated and left the underwear harmless to the insect; if applied in great strength, they irritated the skin of the wearer.

During the first winter the men were in camp, the winter of 1917-1918, there was no time to provide them with standard army underwear. Consequently government agents went into the underwear market and bought outright whatever was in sight. That first winter the soldiers wore underwear of almost every description and grade of merit. This gave the Army's underwear experts a fine opportunity to study the qualities of underwear of various types, as proved by actual

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use. These studies contained hints of use to the civilian. For instance, the warning was plainly given to wear no fleece-lined underwear. A study was made of the causes of colds, and it was discovered that soldiers wearing fleece-lined underwear caught cold more easily than those wearing any other sort. The fleece of the lining absorbed perspiration and retained it, remaining damp. Since many of the soldiers slept in their underclothing, they were thus encased in damp clothes twenty-four hours a day. Sick reports plainly showed the result.

When we come to the production of cotton cloth for the Army's uses, we find the figures so large as to appear almost fantastic. In all, we procured over 800,000,000 square yards of cotton textiles. This was enough to carpet an area nearly four times as large as the District of Columbia. In a strip three feet wide there was enough of it to wrap eighteen layers of cloth around the equator. Spread this strip out on some cosmic floor, and you could place upon it, side by side, fifty-five globes as large as the earth.

In addition to the cotton khaki required for uniforms and other purposes, the principal other cotton items were duck, denim, webbing, gauze, venetian, sheets, pillowcases, and towels.

The purchases made by the Army were beyond anything that had been known in the textile industry. In March, 1918, the supplies of cotton khaki on hand seemed to indicate a surplus of 21,000,000 yards beyond the needs of the immediate future. Then came the start of the German drive, and by the middle of April this great surplus of khaki cloth was not sufficient to the need. In other words, there was a shortage of khaki: the Army needed at once 25,000,000 yards, and thereafter would require a monthly supply of 10,000,000 yards. This was looking toward the great increase in the number of men soon to be called to the colors. It was planned to draft 300,000 in June alone, and subsequent drafts would be on a like scale. In order to supply summer uniforms for these men it was necessary for army officers to get every yard of khaki goods in the country. All stocks of goods in the hands of dealers and manufacturers

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were inventoried, and a positive order went out of Washington forbidding the use of khaki in articles for civilians. In spite of the Government's tremendous demand upon a limited supply, these stocks of khaki were acquired at a price 20 per cent lower than that of the prevailing market.

The requirements for cotton duck and cotton webbing also leaped upward as soon as the United States began to avalanche soldiers upon France. The demands were greater than could be supplied by the output of mills regularly producing these materials, and consequently the Clothing and Equipage Division called upon manufacturers of similar materials to adapt their plants to the production of duck and webbing. This they did, in many instances at considerable inconvenience and expense. Among the concerns which assisted in supplying these materials were manufacturers of carpets, automobile tire fabric, and even lace.

Owing to the scarcity and the high cost of leather, a great deal of cotton webbing was substituted in the manufacture of such equipment as cartridge belts, suspenders, gun slings, and horse bridles. Here was additional demand, and to meet it factories which had been making such things as asbestos brake linings, hose, lamp wicks, suspenders, garters, cotton belting, and other similar fabrics, became webbing mills. All the plants thus adapted to the emergency manufacture of webbing were dependent on purchased yarns, which they had to secure in the open market from yarn manufacturers.

In the South particularly, where most of this yarn was purchased, the securing of power was a serious question. Many of the mills depended upon electricity generated by water power. The power plants did not always have good railway connections, and many of them had no steam power equipment, even if fuel could have been furnished. In the late summer of 1918 the rivers of the South ran nearly dry, and in order to operate many of the southern mills it was necessary for the Government to allocate, according to the most pressing needs, the available power among the mills which were working on contracts. Also, for a long time when transportation facilities were

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seriously overtaxed it was hard to secure a steady flow of materials from the South to the northern mills.

There was also a problem of labor, for employees in the cotton and webbing mills had to be educated in the manufacture of the new types of work to which these plants had been shifted. In the South, more especially, there was a question of child labor and of hours of labor for women and minors; for the Government inserted clauses in the later contracts requiring certain standards for the benefit and protection of labor. In some instances contracts were returned because of the child-labor clause; whereupon compulsory orders were often issued, practically compelling the mills to produce the goods called for.

Considerable burlap used for packing, as well as burlap bags, and silk for flags, hatbands, and badges, were also purchased in quantity. The United States was never forced to turn to the use of paper in the manufacture of clothing, as the Central Powers were compelled to do; nevertheless, preparation was made for the time when the cotton supply of the United States might become unequal to the demand. Garments made of paper cloth captured from the Germans were shipped to the United States and carefully studied by the Clothing and Equipage Division, to ascertain the possibilities of paper fabrics should the need for them develop.

Over 100,000,000 yards of denim were bought. Denim was used particularly in making working clothes for the soldiers. At one time the factories were consuming denim at the rate of 13,000,000 yards a month. Brown denim, which was required by regulations, was a material hard to get, blue being the standard fabric for American overalls; and consequently heavy gray goods and drills were dyed olive drab and put into use.

About 140,000,000 yards of gauze were purchased. Sheets and pillowcases were required in such quantities that at one time every mill in the country whose normal business was the production of sheeting was working for the Government.

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There were over 120,000,000 yards of webbing purchased, and nearly 300,000,000 yards of the various kinds of duck.

The duck and webbing just mentioned went into the manufacture of a numerous class of articles, known as textile equipment, including such articles as belts, tool bags, tool kits, flasks, canteen covers, and the like. The procurement of the webbing for these articles was in itself a manufacturing achievement. Before the war there were only a half dozen plants in the United States which could make webbing of the grade demanded by the Army. When the armistice came, there were 150 such plants. At the beginning of the war an order for 5,000,000 yards of webbing fairly staggered the industry, but that industry was to witness the day when an order for 50,000,000 yards would be absorbed as a matter of course.

But even after the webbing was secured, there were practically no factories in the United States that had machinery heavy enough to make military articles of it. This work for the standing Army had been done exclusively by the Rock Island Arsenal. In order to increase the manufacturing capacity of the country it was necessary to get the Singer Sewing Machine Company to build special machines adapted to this heavy work; and we also had to send experts from the Rock Island Arsenal to teach all new contractors how to make the articles. Many of the factory workers were women.

In spite of all difficulties, production was wonderfully increased. Along in January, 1918, about 100,000 pistol belts a month were being made; at the time of the armistice, 560,000 were being manufactured monthly. Of cartridge belts in the same period the production was increased from 85,000 to about 410,000 monthly, and of haversacks from 290,000 to about 850,000 monthly.

No soldier could be sent overseas without a haversack, a cartridge belt, and a canteen cover; yet during the period of active hostilities no movement of troops was delayed one day on account of the lack of textile equipment. Up to December 1, 1918, the production of haversacks was over 2,500,000 in number, costing over $8,000,000; of canteen covers, about

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3,750,000, costing $2,250,000; of cartridge belts, about 1,500,000, costing over $4,000,000. Another large item was bandoleers, which were procured to the number of over 31,000,000 at a cost of $5,550,000. These few of the major items serve to illustrate the extent of the purchases of textile equipment. At the end of hostilities the Government was buying textile equipment at the rate of $22,000,000 a month, and was working toward the goal of being able to supply 750,000 men a month with all articles of textile equipment.

When, in the spring of 1918, the Army began to expand at an unexpected rate, the expansion created a great shortage in cotton underwear. Government agents went out over the country and bought all cotton underwear stocks. In order to provide a sufficient manufacturing capacity for cotton underwear, women's underwear factories were enlisted for war work, and so were even corset factories.

The army experts in cotton textiles also effected many economies. A standard pattern layout was drawn for the overall makers, with consequent large savings of cloth in the manufacture of brown denim fatigue clothing, or soldiers' working clothes. At one time practically every overall factory in the United States was making fatigue clothing for the Army, after General Pershing had cabled an order for 3,000,000 garments to be delivered in ninety days. In cutting out the pattern of the barrack bags in which the soldiers pack their clothing and personal effects, the manufacturers left a three-inch strip of cloth. Army officers discovered these three-inch strips and also noted the fact that every barrack bag must be provided with a draw string. The specifications were thereupon changed so that these three-inch strips could be used as draw strings in the barrack bags—a trifling economy apparently, yet one which amounted to a saving of six cents in the cost of each one of millions of these bags.

A vast amount of tentage was required, not only for tents themselves, but also for such articles as paulins, tent covers, bed rolls and clothing rolls, canvas basins and buckets, bags

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for tent stakes, tool bags, coal bags and mail bags, cargo covers, wagon covers, horse covers, and many similar articles.

Valuable work was done in substituting cotton thread for linen. Linen thread became so scarce that the Ordnance Department commandeered the whole supply. This worked havoc in the shoe industry, and as a result the Council of National Defense secured from the Ordnance Department enough linen thread to take care of the army shoe contracts. Nevertheless, it was discovered that cotton thread could be substituted for linen in many industries. In fact, it often proved to be better than linen.

Valuable standard tests for waterproof cloth were also worked out. These tests were developed at the Bureau of Chemistry, a branch of the Department of Agriculture in Washington. In these tests, cloth was required to withstand a deluge of water equivalent in intensity to a tropical rain, and also to undergo a dry temperature of 120 degrees Fahrenheit. There were also tests to determine under what conditions the cloth would mildew. These tests are expected to have a use in the waterproof-goods industry in normal times. Another important contribution of the Army to peace-time industry was the design of the oversuit for the use of truck drivers. This was a waterproof garment, air-tight and cold-proof. It is expected that this new garment will continue in commercial use.

The principal items of rubber goods bought by the Army were rubber boots and overshoes, raincoats, and slickers. The production of rubber boots for the Army took practically the entire capacity of all mills in the United States, the rubber boot manufacturers having pledged themselves to discontinue their civilian business until the needs of the Government were taken care of. Of different types of rubber boots, the purchases were considerably over 4,000,000 pairs, at a cost of $20,500,000. Incidentally, there was worked out an improvement in rubber boots to prevent them from blistering the heels of wearers. It was discovered that a rubber boot blisters the heel because it rubs slightly as the wearer walks, no matter how

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well fitted to the foot the boot may be. To the specifications for the Army's rubber boots was added the requirement that straps be incorporated in the boot, to be buckled both around the ankle and around the instep, holding the boot so that it could not slip.

Raincoats caused a good deal of trouble, as there was not a sufficient manufacturing capacity in this country to meet the requirements. Practically all stocks of commercial raincoats were purchased on the theory that even a poor cover was better than none. As these garments were made for civilian use, they were not built according to army specifications, and considerable criticism was made of their quality. When the war manufacture of raincoats began on a large scale, many new concerns went into the business, and some of them, either through lack of experience or through carelessness or intent, made garments that were not properly cemented. This led to investigations and indictments. The total purchases of ponchos, raincoats, and slickers amounted to about 10,000,000 garments, costing over $46,000,000.

In all, 7,000,000 service hats of felt were manufactured on orders placed by the War Department. The felt for these hats was made in the United States of rabbit fur imported from Australia, New Zealand, and Russia. Hats were made principally at Danbury, Connecticut, and Fall River, Massachusetts, with smaller sources of supply at Yonkers and Peekskill, New York, and Reading, Pennsylvania.

The numerous requirements of the Army for pillows created a shortage in feathers. In all, there were manufactured on government order 500,000 pillows weighing 2½ pounds each. It had been the original intention to fill these pillows with duck feathers; but when the American duck-feather supply was exhausted and thousands of the ducks of China had given up their plumage for the comfort of the American soldiers, and still there were not enough feathers for the pillows, adulterations with goose feathers and other light plumage were permitted.

The procurement of leather for the Army, both in raw

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material and the finished products of leather, was one of the most important undertakings, the principal war uses for leather being in shoes for the soldiers and in harness for the horses and mules. When the Government entered the leather market it found a high level of prices, due to the large quantities of leather and leather equipment which America had been exporting to the European nations at war. The tanners were called together, and they came to an agreement with the Government as to the prices of all grades of equipment which the Army expected to buy. The packers next agreed on a maximum price for hides suitable for army leathers. The Government took an option on 750,000 hides then in the hands of the packers. By consulting with the industry at all times, the government officers were able to stabilize prices of leather. The price of harness leather, which was originally fixed at 66 cents a pound, was advanced only 4 cents during the eighteen months of the war period, and russet leather never advanced more than 4 cents a pound above the $1.03 fixed at the beginning of the war.

As the stocks of leather on hand diminished it became necessary to stimulate its production, and there was formed a hide and leather control board, with a representative on it from each branch of the trade, one for harness, one for sole leather, one for upper leather, and one for the sheepskin trade. This board also inspected leather at all the tanneries and the finished leather in the various factories, a course which resulted in great improvement in the quality of leather, particularly that used in shoemaking.

At the outset the Quartermaster Corps, the Ordnance Department, the Signal Corps, the Engineering Department, the Medical Department, the Navy, and the Marine Corps were all buying leather or leather equipment, and the Y. M. C. A. and the Red Cross were also in the market for large amounts of leather materials. These activities, except those of the Navy and Marine Corps, were all eventually brought under the administration of the Clothing and Equipage Division, thus virtually eliminating competition in the leather market.

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It is safe to say that at the signing of the armistice there was enough leather equipment, either in the United States and France or in process of manufacture here, to meet the needs of 5,000,000 men. Leather equipment was available at all times. The principal military articles of leather were harnesses, shoes, jerkins, gloves, and mittens.

In all, $75,000,000 was spent for harness and leather equipment. The procurement of saddles was a hard problem in itself, for there were only three or four makers of saddletrees in the United States, and only one of these could get the ash or basswood required. The division induced various furniture factories to install the special lathes required for turning saddletrees, and in this way built up eight factories, which gave us sufficient capacity. Belting manufacturers and manufacturers of shoes were educated in the art of producing the leather for the saddles. The army harness is of russet leather, and russet leather harnesses are a product for which there is no commercial demand. The result is that the surpluses of army harness could not be disposed of to advantage after the armistice.

The former American army shoe built on the Munson last and known as the russet marching shoe was machine sewed, had an upper of calfskin with the rough side turned in, and was lined with duck. This shoe proved to be short-lived when subjected to the severe service in France. At the beginning of the war a new shoe was designed for trench service. This was a much heavier shoe, with the calfskin of the upper turned rough side out. There was no lining in the shoe. It had two heavy soles, the outer one hobnailed. Yet this shoe, too, proved to be unsatisfactory. The uppers wore fairly well, but the soles could not stand the constant submerging in mud and water.

The demands of trench service eventually led to the design of what was called the Pershing shoe. This was a shoe with three heavy soles, stitched, screwed, and nailed together. It had steel reinforcements on toe and heel. The outer sole was studded with hobnails. The original requisitions from France for this shoe called for leather tanned with bark. As bark

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tanning is almost obsolete in the United States to-day, it was necessary to go into the tanneries and build up what was virtually a new industry. It should be mentioned that the design for the Pershing shoe was completed in thirty days. The culmination of the shoe development was the model known as the Victory shoe. This model corrected certain defects in the Pershing shoe. The Pershing shoe was prone to rip along the back stays, and the upper did not fit snugly. In the Victory shoe the entire back of the upper was one piece.

At one time fifty-two shoe factories in thirteen states were working on army shoe contracts. A scheme of packing shoes for overseas shipment in burlap bags instead of in boxes resulted in saving a great deal of space on board ship.

Machinery and tools for the shoe repair shops of the salvage division were purchased by the Clothing and Equipage Division. This was the first time that Uncle Sam had ever acted as cobbler for his soldiers. About 2,000 machines for repairing shoes were bought, besides some 28,000 repair kits, each one of which cost $135. Among the items of supplies for the army shoe repair shops may be noted 20,000,000 pairs of half soles.

A shoe waterproofing grease, or dubbin, as it is called, which had no odor and would not turn rancid, was developed. The experts worked closely with officers in the field in training soldiers in the care of shoes to make them last as long as possible. Every man who received a new pair of shoes was required to break the pair in by standing in them in water for a certain period and then walking for an hour until the shoes dried on his feet. The men were cautioned not to dry their shoes by placing them too near any heating apparatus, as this shortens the life of the leather. Good care of the soldier's feet has long been standard army practice with us. No soldier in 1917 and 1918 was permitted to wear darned socks unless he wore two pairs at once. At regular intervals officers inspected their men's feet, treated any blisters or sores, and dusted the feet with powder.

Bad shoe fitting means foot troubles, leg troubles, and sometimes even spinal and mental troubles. E. J. Bliss, a Boston manufacturer of shoes, developed a shoe fitting system which

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was adopted as being unexcelled. The fitter was an implement about like a roller skate, with movable wings on the sides and a movable plunger in front of the toes. The soldier to be fitted equipped himself with rifle and loaded pack. With this weight on his shoulders he stood with both feet upon the skate-like devices and then rose on the balls of his feet until the weight and movement pressed out the wings as far as they would go and advanced the front plungers. With the size thus automatically determined, the next step was to check its accuracy. This was done by inserting a pair of implements with knob-like ends in the toes of the shoes, the implements just filling the space in front of the soldier's toes. Wearing shoes and implements, the soldier then walked about the room, stepped upon a platform, climbed a cleated ramp, and otherwise simulated the actual service demanded of shoes in the field. If the checking implements in the shoes did not hurt his toes, the fit was regarded as correct.

Clothing and Equipage Production to November 11, 1918

	Produced	*Shipped overseas*
Blankets	19,419,000	3,127,000
Coats, denim	10,238,000	3,423,000
Coats, wool	12,365,000	3,871,000
Drawers, summer	38,118,000	3,889,000
Drawers, winter	33,766,000	10,812,000
Overcoats	7,748,000	1,780,000
Shirts, flannel	22,198,000	6,401,000
Shoes, marching and field	26,423,000	9,136,000
Stockings, wool, light and heavy	89,871,000	29,733,000
Trousers and breeches, wool	17,342,000	6,191,000
Undershirts, summer	40,895,000	4,567,000
Undershirts, winter	28,869,000	11,126,000

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CHAPTER XXXI

MISCELLANEOUS QUARTERMASTER UNDERTAKINGS

SERGEANT IRVING BERLIN, one of the fountain sources of American jazz music, found a special job cut out for him when he was drafted into the military service. The needs of the war machine called upon a wide range of individual talents, and this range did not exclude the artists. The painters engaged in camouflage work and made sketches and pictures of such things as unusual surgical operations for the permanent records of the Government, the poets fired the zeal of the country, and the musicians inspired the soldiers by providing them with music.

The American Expeditionary Forces, as they grew in size, found themselves possessed of some 390 regimental bands. These bands organized themselves, gathered such music as they could get, practiced, and presently regaled the soldiers of units to which they were attached; and then the inevitable happened—they played and played the same old pieces until their audiences yearned for something new. One day a cry of distress trickled through the cables, and then the plight of the hapless lover of band music in France became the problem of the quartermaster organization in the United States. It resulted in the largest purchase of band music ever made—200,000 sheets of it, costing nearly $50,000.

The music problem of the American Expeditionary Forces was put into the hands of a special committee of three well-known authorities in the musical world. Sergeant Berlin was the authority on popular numbers; Lieutenant R. C. Deming, the bandmaster at Camp Meigs, Washington, D. C., was the member in charge of the ceremonial numbers; and Mr. Ward

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Stephens, the well-known composer, organist, and accompanist, was in charge of the concert numbers. This committee picked out a repertoire of 333 selections, consisting of 172 concert pieces, 43 ceremonial numbers, and 118 popular numbers. Four hundred complete sets of these were bought, one for each of the 390 bands of the American Expeditionary Forces, with ten sets as a reserve. The music was bought from some twenty-seven music publishers, the largest suppliers being Carl Fischer, the Waterson, Berlin & Snyder Company, the Leo Feist Company, the Jerome H. Remick Company, and G. Schirmer (Inc.), all of New York, and the Oliver Ditson Company, of Boston. Each complete set was packed in a separate case, so that each case, upon arrival in France, could be sent immediately to a band of the American Expeditionary Forces without being disturbed. The sorting and packing of this consignment of sheet music was handled by Sergeant Berlin and a staff of technical musical assistants, who, at his request, contributed their services.

The supply of music was but one of hundreds of enterprises required to make the Army efficient, comfortable, and happy, quite aside from the more obvious ones of supplying guns and ammunition, artillery, aërial observation, and food and clothing. And these scattered undertakings in military supplies accounted for the expenditure of hundreds of millions of dollars. Nearly all of them were quartermaster enterprises. But before we lift the curtain on this, one of the most interesting branches of our military preparation, involving, as it did, the scientific solution of problems ranging from the production of supergasoline for the fighting airplanes to the proper and most economical method of cutting up the carcass of a steer, let us continue the musical overture by observing how the Army secured its band instruments.

There was a special branch of the Quartermaster Corps which concerned itself exclusively with the musical requirements of the Army. This branch bought, in all, approximately 143,000 musical instruments. These were secured at a saving of about $500,000 under the prices which the Government had

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been paying for such instruments prior to the war. Without going into the details of how this economy was effected, one typical instance may be cited. For years it had been the custom of manufacturers of musical instruments to embellish the trumpets and brass horns of bandsmen with engraving, chasings, and other markings. These were decorative only and had nothing to do with the quality of tone produced. By eliminating all such markings from the specifications, a substantial saving in cost was attained.

The principal suppliers of musical instruments were the William Frank Company, of Chicago; J. M. York & Son, of Grand Rapids, Michigan; and the H. M. White Company, of Cleveland, Ohio. C. S. Conn & Company, of Elkhart, Indiana; the Eugene Beisler Company, of Chicago; and the Rudolph Wurlitzer Company, of Cincinnati, also supplied several thousand musical instruments.

FUEL, OIL, AND PAINTS

DURING the months of hostilities the American public was constantly informed in advertising literature that fuel would win the war, and indeed fuel would win it, and did win it, in the sense that without fuel or with any grave shortage of fuel we could not have won. In this sense, no commodity contributing to success in the great drama was more important than coal. Coal not only furnished the power that transported the khaki-clad millions to France, but it furnished the manufacturing power in the United States and supplied the coke which is essential to the manufacture of steel, thus entering into every rifle and every piece of artillery.

America began keeping the records of coal mining in the year 1807. Woodrow Wilson was inaugurated President of the United States in 1913. In the 106 years, 1807-1913, American mines produced a total of 9,844,159,937 tons of coal. In the succeeding five years of President Wilson's administration American mines turned out 2,960,938,597 tons of coal, almost one-third as much as was mined in the entire 1807-1913 period, and almost one-fourth of all the coal mined in

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the United States since records have been kept. The American coal miners in 1918 met the war emergency by producing 150,000,000 tons of coal more than they had dug in 1914. The shortage of coal in the winter of 1917-1918 was due, not to the inability of the mines to produce the required tonnage, but to inadequate railroad transportation facilities and severe weather conditions.

The war-coal project was in the hands of the United States Fuel Administration, but the office of the Quartermaster General assisted in the effort. Army officers were stationed at the offices of the various district representatives of the Fuel Administration throughout the country. These officers kept in constant touch with the factories making war supplies and saw to it that coal was diverted to them from less essential enterprises. This service operated with such excellent effect that few manufacturers working on government contracts were compelled to suspend operations because of lack of fuel, and those who did have to suspend were able to resume again within a few days.

During the summer of 1918 the usual seasonal slack in the demand for fuel was taken up by the action of the fuel branch in absorbing practically all the excess coal in the United States and storing it at army posts, camps, and stations. This action kept the mines working at maximum capacity during a period when there is normally a curtailment in output. Of course, at the time there was no realization that the fighting was to end so soon, and this policy was adopted in preparation for unchecked industrial activity during the winter of 1918-1919.

The Army was an enormous consumer of oil, the total oil purchases, both in the United States and in France, in the nine-month period from April 1 to December 31, 1918, amounting to $30,522,837. There were forty-nine items in the oil-purchasing schedule for the troops in the United States alone, including lubricating oils, fuel oils, oils for paints and varnishes, gasoline for motor trucks and airplanes, axle grease, floor oil, tempering oil, oil for the preservation and waterproofing of shoes, harness, and other leather equipment, and

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numerous other varieties of oils. The gasoline purchases were heaviest of all, army motor trucks and cars in the United States requiring 484,282 barrels of it, worth $5,448,570, in the nine months between April 1 and December 31, 1918. The American army motor trucks and cars with the American Expeditionary Forces were supplied with 703,104 barrels, worth $10,104,437, in the same period. For army airplanes in the United States during the same months there were purchased 306,082 barrels of special aviation gasoline, at a cost of $3,906,650, and for the planes in France 146,780 barrels, worth $2,748,839.

To give the American aviator the hottest, most instantaneously explosive, and surest-fire gasoline ever produced, the American refiners turned out, according to specifications drawn by the Government, a naphtha that was the highest refinement of gasoline ever produced in large quantities. This was done by taking the best gasoline that had ever been produced in commercial quantities and giving it another run through the distilling retorts. Thus it was the cream of the cream, containing only the most combustible elements of liquid fuel and nothing else. This refinement became known as "257-degree fighting naphtha," and the Army confined its use to the service planes actually at the front. It was not supplied to the aviation training camps, either in this country or in France. In order to distinguish this naphtha as the finest engine fuel available and to mark it so that it would not be wasted by accident in any use other than that of service at the front, it was colored red with aniline dyes. The Army did not even trust 257-degree fighting naphtha to bulk transportation on tank ships, but stored it in steel drums and freighted it across the ocean in this form in cargo boats.

America has always been the largest producer of gasoline, and experience and development in this country have resulted in many grades of the fuel. The ordinary commercial gasoline comes in five grades, the best grade being known as "straight-run" gasoline and the other grades, in the order of their cost and purity, as "casing-head," "blended," "pressure-still," and

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"cracked." For motor fuel for the Army the quartermaster specifications would accept nothing but "straight-run" gasoline, unblended and without dangerous additions which have a damaging effect upon motor cylinders. This gasoline, the best that could be bought by the civilian users, is known as "428-degree gasoline"; and it was the fuel used universally in our motor trucks and motor cars.

Above that were the three grades of gasoline, or rather, naphtha, produced specially for the American army airplanes. The lowest grade of these was called domestic aviation gasoline, and it was the best commercial gasoline refined until its boiling point had been brought down to 347 degrees F. This fuel, used by our aviators in this country, was known as "347-degree domestic aviation naphtha." A still greater refinement was the splendid "302-degree export aviation naphtha," which was used by planes in France other than those at the front. The fighting naphtha was obtained by taking the cream of export aviation naphtha. Although purchased in enormous quantities, it cost the Government more than 41 cents a gallon. The Government paid slightly less than 22 cents a gallon for its motor gasoline.

Another new development in the oil industry brought about by the Government's war needs was known as "Liberty aëro oil." This was an airplane lubricating oil of pure mineral origin, a refined lubricant of excellent viscosity and a low cold test, an oil which proved itself to be capable and reliable under the ever-changing atmospheric and pressure conditions of mechanical flight at the front. Liberty aëro oil was a success. Most of it which was shipped overseas was made from paraffin base oils, although in this country we used successfully many aëro oils of asphaltum base.

The Ordnance Department submitted a requisition for a three-months' supply of pure neat's-foot oil, which was in quantity almost twice the total American production of neat's-foot oil in the preceding year. The government oil experts worked out a satisfactory substitute by combining animal and mineral oils. This was not only equal to neat's-foot oil under

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tests, but it was considerably cheaper. The American Expeditionary Forces submitted a rush order for 6,000,000 pounds of dark axle grease. The specifications called for containers made of tin. But it was almost impossible to secure the tin for such a shipment. Experiments were conducted with all possible haste, and the result was a container made of black sheet iron treated with a special varnish to prevent the moisture in the grease from rusting the iron. This container proved to be satisfactory.

BRUSHES

OFFHAND, one would scarcely say that brushes play any part of vast importance in the life of an individual; yet to buy the brushes for the Army required a special organization, competent to spend money by millions of dollars and get value received for it. Indeed, it was astonishing what a variety of brushes the Army required. The toothbrush, the shaving brush, the hairbrush, the clothes brush, the shoe brush, and the paintbrush might occur to anybody as necessaries; but the Army used all these and, in addition, artists' brushes, bottle brushes, chimney brushes, whitewashing brushes, gun-cleaning brushes, floor brushes, roofing brushes, stove brushes, horse brushes, and dozens of other kinds. In all, the Government bought 9,224,210 brushes, at a cost of $3,039,000. It required fifty-nine factories in the United States to manufacture these brushes. The most numerous class of all was the toothbrushes, more than 1,500,000 of these being ordered from one company alone.

Brushes are made from many different materials, such as bristle, horsehair, fiber of various kinds, imitation bristle, split quills, and the like; but the most important is bristle. Only a little bristle is produced in the United States in comparison to the demand for it, the bulk of the supply coming from China, India, Siberia, and Russia. The procurement of bristle was no small part of the problem of supplying brushes for the Army. Not one in every ten toothbrushes used in the United States was of American manufacture before the war, the rest

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coming from Japan, France, England, Germany, and Austria. When the European supply was cut off, Japan became the principal source of supply. The problem of toothbrushes was further complicated by an embargo on bristles coming into this country and another on the exporting of bone to Japan.

The Army bought no shaving brushes made of horsehair, even in part, for horsehair is known to be the carrier of the much dreaded anthrax germ. The Government specified a shaving brush with an abbreviated handle, making it more convenient to carry. A handleless hairbrush was also specified. Paintbrushes were largely standardized; but it was impossible to standardize toilet brushes, because there were not enough facilities in the country to turn out sufficient quantities, if machinery were to be remodeled to meet government specifications.

ROLLING KITCHENS

Those in charge of general quartermaster purchases designed and produced the Liberty rolling field kitchen, an equipment which could cook for 200 men. Rolling field kitchens were not new to our Army or the trade, there being about six types of commercial kitchens manufactured at the time we entered the war. Most of these were being produced on foreign war orders. In order, however, to secure a standardized kitchen with interchangeable parts, thus ensuring a constant supply of spare parts, the division designed the Liberty kitchen. There were two types—the horse-drawn type and the motor-drawn or trailmobile type. Each kitchen consisted of a stove and a limber. The stove unit contained a bake oven and three kettles. The limber contained four bread boxes which were also used as water containers, one cook's chest, four fireless cookers, and four kettles. In July, 1918, contracts were awarded for 15,000 complete kitchens, including the necessary cooking and camp utensils. Deliveries of these kitchens eventually reached a rate of over 200 a day. Two factories adopted and installed track conveyor equipment on which the assembling process was carried forward from operation to operation until the finished

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kitchens, painted and boxed, were delivered to the cars for shipment to the port of embarkation. The kitchens were packed each in a single crate, ready to be delivered to the front after arriving in France.

Before this kitchen was designed the Army had been paying from $700 to $1,050 apiece for rolling kitchens. The average price of the Liberty kitchen was $502. Subsequent orders brought the total projected purchases of mobile kitchens to 25,000, of which 10,000 were of the animal-drawn type. Substantial shipments of these kitchens had been received overseas before hostilities ceased, and in November deliveries were expanding at a rate which, by January 1, 1919, would have exceeded several times the 3,000 Liberty kitchens required by the American Expeditionary Forces. About 7,000 rolling kitchens of all types were shipped to France.

TOOLS AND TOOL CHESTS

Another important result accomplished in the purchase of general supplies was the standardization of tool chests. At one time the Army was buying and using approximately 100 different kinds of quartermaster tool chests. A committee to standardize tools and tool chests was appointed, and this committee reduced the number of types of tool chests to seven standardized ones—the carpenter's chest, the blacksmith's, the farrier's, the saddler's, the electrician's, the plumber's, and the horseshoer's emergency chest. Standardization of tool chests effected a large saving in transportation space by keeping the dimensions to a minimum. The standardized carpenter's chest occupied three and one-half cubic feet less space than the older type wooden chest. Since at the time the armistice was signed the Army was in the market for approximately 135,000 tool chests of the seven standardized types, the saving in shipping space would have been no slight achievement. But there was also in sight an enormous saving of money, not to speak of the fact that standardization would greatly have increased the rate of manufacture.

The committee also standardized the tools. Many varieties

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of such things as drawknives and handsaws had been purchased previously. This committee adopted a standard type of drawknife and a standard handsaw, and also standardized many other tools.

HARDWARE

The general supplies division of the quartermaster organization operated much of the Army's hardware store. In this work the division not only standardized army tools, but also standardized the proportions in which the various tools were bought. This was not only an intensely interesting development, but it was of utmost importance to the American people, since it saved large sums of money and great quantities of shipping space.

The supply officers of the American Expeditionary Forces early began making up their estimates of the materials that must be produced in the United States and shipped to France, to maintain the efficiency of an indefinitely growing Army over a protracted period. In hardware these estimates came originally from the company units. Each repair unit, for instance, would look over the future, and its officers would estimate kinds and quantities of tools required for such and such a period. These little estimates came together in larger groups, and so on, the consolidation of figures continuing until eventually, to represent a certain tool, there would be one figure on file at headquarters. Then one day one of those long daily cablegrams from France, signed "Pershing," came to Washington, bringing the future requirements for tools and other hardware.

Theoretically it might be assumed that the proportioning of items in these requisitions would be correct and that the American Expeditionary Forces might be expected to need tools in the proportions named. Of course, Sergeant A, in a repair unit with the artillery, might estimate too many hammers and too few wrenches, but Machinist X, miles away in some base shop, might call for too many wrenches and too few hammers. These two estimates would thus balance correctly; and, following out this line of reasoning, it would seem that the entire Ameri-

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can Expeditionary Forces' hardware requisitions, compiled as they were, would be properly proportioned. Yet when these requisitions came to Washington and were found to call for the manufacture of such things as files and bolts by tens of millions, the supply officers here would not accept the theory that the proportions of various sizes called for were correct, but turned the searchlight of science upon these estimates.

The method selected for checking these estimates was simplicity itself; yet it was unique in the history of American industry and almost majestic in the scope of its comprehensive vision. The officer in charge of the procurement of hardware, in considering, for instance, files, simply called together the entire file-manufacturing industry—and that means that not a single manufacturer was overlooked—and asked that industry to assemble the results of its experience over a period of the last five or six years. Each manufacturer would show, for instance, how many flat files he had sold of each length and of each type of cutting surface,—either bastard, second-cut, or smooth,—how many half-round files, how many hand files, how many round files, how many square files, how many warding files, how many knife files, how many taper files, and so on, all by lengths and by cutting surfaces. When all these experience figures were assembled, the officers in charge at Washington knew exactly in what proportions the whole American industrial world had used files of various types throughout a considerable period of time.

This procedure was followed with respect to many common articles in hardware. The Hardware Manufacturers' Association for War Service was formed to give just such assistance, coöperating up to 100 per cent of the hardware industry. The consolidation of the experience figures in American hardware consumption resulted in a schedule of supplies known as the Army's hardware tariff, a schedule showing the proportions in which hardware might be expected to be consumed.

The hardware tariff disclosed some surprising errors in the estimates from the American Expeditionary Forces. The American Expeditionary Forces' requisitions, for instance, had

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called for a total of 127,180,387 bolts of various kinds. The experience of bolt consumption in the American industry was able to correct this to a total of 125,285,000 bolts, or a saving of nearly 2,000,000 in number of pieces. The requisitions had called for 39,945,458 large carriage bolts. The experience of American consumption showed that only 9,700,000 large carriage bolts would be required. The original specifications had called for 31,839,741 small carriage bolts. The experience in American consumption showed that 60,300,000 would be necessary. In other words, the offhand estimates of the American Expeditionary Forces had called for 30,000,000 large carriage bolts too many and nearly 30,000,000 small carriage bolts too few. The specifications from France called for 5,000,000 stove bolts of the five-eighths-inch dimension. Since this size was not used or was not made at all by stove-bolt manufacturers, the item was canceled, and 2,000,000 smaller-dimension bolts substituted.

All bolts were supplied in quantities and proportions determined by following the proportions of this scientific tariff. They were shipped to France in these proportions, whence reports from the American Expeditionary Forces showed that the quantities sent completely covered the needs of the troops in the field. The saving in the manufacture of bolts alone came to nearly $4,000,000, and this says nothing of the saving in railroad and ocean freight charges, or the still more important saving in ocean tonnage space, since the bolts supplied according to the scientific tariff occupied many hundreds of cubic feet less space than the bolts originally specified would have filled.

The same procedure was followed in the supplying of files. The hardware manufacturers consulted their records and, on the basis of actual consumption in American industry, discovered that a repair unit consisting of a machine shop, a horseshoeing shop, a blacksmith shop, and a woodworking shop, with eleven mechanics working in the unit, would consume 305 dozen files a year, the experience tables showing precisely the proportions of the various sizes of files in this consumption. Consequently, when the American Expeditionary Forces re-

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CRATED CAISSONS

Photo from Quartermaster Department

PARK OF AMERICAN ROLLING KITCHENS

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Photo from Quartermaster Department

ARMY HORSE COLLARS IN STORAGE

Photo from Quartermaster Department

METHOD OF STORING ROLLING KITCHENS

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quested 439,200 dozen files, the quantities of each size, kind, and style as specified in the requisition from France were disregarded, and the so-called tariff proportions substituted. The files as supplied not only proved adequate in number in every style, but they cost $250,000 less than it would have cost to fill the original order. Moreover, by using tariff sizes the industry was able to make immediate shipments and to run at full production from the start, since it needed only to produce files in the proportions known in the regular trade.

What was done with bolts and files, then, was done in many other departments of hardware. When the American Expeditionary Forces saw that its hardware was coming in correct quantities, its officers notified the hardware supply organization to ship all tools and hardware materials in accordance with the so-called tariff. The executive committee of the Hardware Manufacturers' Association for War Service, which made possible this achievement in commercial science, consisted of Messrs. Murray Sargent, Alexander Stanley, Charles W. Asbury, Fayette R. Plumb, and Isaac Black.

The standardization of proportions in the hardware supply succeeded in cutting an original requisition of the American Expeditionary Forces for 8,750 tinners' machines to 860, and an original requisition for 21,600 tinners' assorted groovers to 240, and still met every need of the Army's tin shops in France.

The army hardware office was also called upon to supply such small hardware as fasteners for gas-mask knapsacks and pistol holsters, and some metallic parts for cartridge belts and similar goods. Less than two months before the armistice was signed, orders were in sight for the manufacture of some 500,000,000 pieces of these small metallic devices. Most of them were to be made of brass. The uses of the Army in October, 1918, were calling for these articles in such quantities that it required approximately 250,000 pounds of brass each working day to meet the demand.

At one time there came an order to procure 135,000,000 stud fasteners within approximately ninety days. The result was that one manufacturer who had been producing 400,000 such

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fasteners in a day succeeded in raising his production to 1,000,000; and this was only typical of the expansion elsewhere in the industry. The demands of the Army overtaxed the brass rolling-mill capacity of the land. The hardware specialists thereupon investigated the possibility of substituting iron and steel for brass, and the substitutes were under consideration when the war came to an end.

Vast quantities of large sizes of rope were requested for overseas to replace steel hoisting cables, which could not be secured in sufficient quantities. Standard specifications drawn by the Government in coöperation with rope manufacturers ensured the supply to the Army of rope of only the highest grades. Approximately 14,000,000 pounds of manila rope, 2,500,000 pounds of halter rope, and 2,000,000 pounds of cotton and jute twine were purchased at a cost of approximately $9,000,000.

Army hardware men bought 1,534,679 axes at a cost of $1,838,979. They bought 1,256,994 shovels at a cost of $1,140,412, and 425,522 wrenches costing $395,776. They purchased 380,752 fire extinguishers at a cost of $1,761,711. They purchased 2,621,521 safety razors and 45,300,000 safety razor blades, the razors costing $3,171,806 and the blades $1,318,750. These items, selected at random, give some idea of the extent of the Army's hardware business.

QUARTERMASTER FACTORY ENTERPRISES

It may not be generally known that the quartermaster organization was an extensive manufacturer of war goods in government shops. In the preceding chapter has been described the method by which the Army was supplied with clothing. Many of the clothing contractors were private manufacturers, but the Government itself manufactured more uniforms than it secured from any single outside source.

There were two government uniform factories—one at the plant of the Philadelphia Quartermaster Depot and the other at the Jeffersonville (Indiana) Quartermaster Depot. The Philadelphia factory also manufactured chevrons, flags, and

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tents. The Jeffersonville depot produced army shirts in addition to outer clothing. It expanded during the war until it became the largest shirt manufacturing establishment in the world. When the armistice was signed the Philadelphia uniform factory was rapidly gaining the eminence of being the largest clothing manufacturing plant in the United States. The total value of the articles manufactured by the Philadelphia Quartermaster Depot during the war was $26,230,000. The garment factory at Philadelphia, started in June, 1918, in five months turned out 751,883 garments and 45,578 flags of various kinds. It was working toward an output of 12,000 pairs of trousers and 6,000 woolen coats a day. There were 3,000 employees in the shop and 2,000 outside seamstresses. The outside seamstresses made denim jumpers and trousers, white clothing, and olive-drab shirts, the production of shirts alone reaching a total of 1,359,801 garments. The Philadelphia factory attained an output of 5,000 pairs of chevrons a day, most of them embroidered, by hand or by machinery. Before the war the Philadelphia factory had had a maximum capacity of sixty-eight pyramidal tents a day. This output was raised to 300.

The Jeffersonville uniform factory was established in February, 1918. Jeffersonville is only a few minutes' ride from Louisville, Kentucky, which is a clothing center, and therefore there was little trouble in securing experienced workers. The factory was operated day and night with two shifts, each working eight hours. The plant reached a daily capacity of 750 woolen coats and 1,500 pairs of woolen trousers. The salaries of the women employees ranged from $50 to $80 a month. The Government established at Jeffersonville one of the most modern woolen cloth shrinking plants in the United States; it cost approximately $50,000 and provided a capacity for sponging 10,000 yards of cloth a day. The army supply officers pronounced the uniforms turned out at Jeffersonville to be the best and most honestly made clothing delivered to the Army during the war; yet the cost of manufacturing uniforms in this plant was at least 25 per cent under the average price

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paid to private contractors. The average cost of making a woolen service coat at Jeffersonville was $1.02; of a pair of woolen trousers, 54 cents.

The shirt factory at Jeffersonville was that depot's largest manufacturing enterprise. It had been making army shirts since 1872. The shirt factory greatly expanded during the Spanish-American War, until it was employing nearly 2,000 operatives, mostly home workers. Thereafter it continued to make shirts at the rate of about 200,000 a year until the United States declared war against Germany, and in that time it had accumulated a roll of 2,000 sewing operatives who had worked for the factory at one time or other. When the great demand for shirts came, in the spring of 1917, the most expert of these seamstresses were hired outright by the month to act as instructors in the homes of new sewing women who had volunteered for the work. Advertisements were then sent out through the newspapers of that entire section for women workers, and presently the factory had a sewing force of 20,000 operatives, from practically every town and village throughout southern Indiana and northwestern Kentucky. The output of shirts was increased from 600,000 a year to 8,500,000. Each home worker was supplied with one complete shirt to be used as a guide, and she secured from the factory, as often as she needed it, shirt material cut from the pattern and tied up in bundles of ten sets. A large corps of sanitary inspectors was employed to visit the thousands of homes and see to it that the shirts were made under proper conditions. All shirts accepted from the home workers were thoroughly fumigated before being issued from the depot.

SHOE FITTING

The Quartermaster Department, along with its other activities, was a school-teacher on a large scale. Without going into a general description of the quartermaster schools and the branches they taught, we will here consider two of the most interesting educational enterprises: the shoe-fitting schools and the schools for butchers.

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Elsewhere in this volume the mechanical system of shoe measuring, perfected and adopted by the War Department, has been described. Studies were made at the camps at various times during 1917 and 1918, studies which examined nearly 59,000 men and showed that a few more than 70 per cent were wearing shoes too short, more than 9 per cent were wearing shoes too long, and less than 19 per cent were correctly fitted. It is probable that these proportions ran clear through the Army before shoe fitting was scientifically taken up, and there is no reason to believe that in civil life the averages of correct shoe fitting are any better.

After the so-called Resco system of shoe fitting was adopted, schools for shoe measuring were held at Camp Meigs, D. C., and at Jefferson Barracks, Missouri. Each camp and cantonment in the country sent two officers to one or the other of these schools. The course of instruction lasted five days and consisted of lectures by experts and demonstrations of the various appliances. In this way the science of correct shoe fitting was scattered throughout the Army.

MEAT CUTTING

It is no easy trick to teach a man to cut meat properly; butchering is a skilled trade. As soon as it was evident that the American Expeditionary Forces in France were to be greatly expanded in size, our officers overseas sent requests that several trained and experienced butchery companies be sent over to cut meats properly for the organizations abroad. In order to comply with this request there was added to the curriculum of the quartermaster training camp in Florida a butchery course in the cutting, boning, rolling, and tying of fresh and frozen beef.

In this course there was developed an entirely new method of cutting beef, known as the "natural guide" method; and by it men who had never cut meat before were developed into practical meat cutters in less than eight weeks of instruction and practice. The natural guide method, which was found to be far superior for army use to any other meat-cutting system

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which had been known, was exactly what it was named, as it was essentially a separating rather than a cutting process. The beef quarters were boned and divided into their major parts by following the natural separations between muscles, tissues, and bones. This method, which is not at all like that in commercial use, proved to be more economical than any meat-cutting system known, because it utilized every ounce of meat and produced a greater proportion of choice cuts suitable for pot roasts and other roasts than the older *Army Cooks' Manual* method of meat cutting. The *Cooks' Manual* method was similar to the method used by the retail butcher, in that it cut meat along artificial lines. The natural guide method actually produced 3 per cent more edible meat than the other method; for even the most expert meat cutters can not remove all meat from the bones by the *Cooks' Manual* method. Moreover, by the natural guide method all cuts are uniform, and the fats, suets, and bones are separated as clean, sweet, edible products. Butchery companies were trained by the natural guide method and sent overseas in numbers sufficient for the requirements of the American Expeditionary Forces.

After the discovery of this method and of the fact that it produced at least 3 per cent more meat than even the expert cutters could secure by the artificial cutting system, it was evident that further research work in the same province would be profitable. Even expert butchers, in spite of all their skill and care, wasted meat. What must be the conditions in the mess kitchens of the Army, where the cooks, with no expert knowledge of butchery, cut the meats? It was evident that numerous edible by-products of meat, such as fats and marrow, were going into the kitchen garbage pails and thence to the rendering plants. The result of the investigation was a project to establish central meat-cutting and rendering plants for all large concentrations of troops, where all meats would be cut, boned, rolled, and tied by experts, and delivered direct to the company kitchens, ready for roasting or cooking in any manner. The fat and suet at such plants, not being soiled or made unsound by handling, could be rendered and its food

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value retained. The oil could be cooked from the bones as a valuable by-product, the bones could be dried and sold commercially, and the plant could also have machinery for making sausage and hamburg steak. A plant of this description was put in operation during the summer and autumn of 1918 at Camp Johnston, the quartermaster training camp, and it proved to be a complete success. When the armistice was signed, the General Staff was considering the proposal to establish these centralized meat plants at all the larger camps.

The meat experts also effected notable economies in ship space by devising what was known as shankless beef. Shankless beef was beef quarters with the four shanks removed. Quarters thus prepared occupied 14 per cent less freezer, cargo, and shipping space than quarters with their shanks.

A still further economy in shipping space was projected in the plan to bone all beef at the packing plants and ship it boxed or frozen in molds and wrapped in burlap. This method, which saved about 50 per cent of cargo space, began to be extensively used during the winter of 1918-1919. One set of packages included tenderloins, sirloins, butts, loin steaks, top rounds, and shoulder steaks. Another set of packages contained roasts, including prime ribs, rumps, bottom rounds, and bottom chucks. A third set was for stews, including flanks, plates, blades, necks, shanks, and trimmings.

HORSES AND MULES

The Quartermaster Corps was charged with the duty of providing horses and mules for the Army. This function is known technically as remount, and the buying of horses was in the hands of the remount division.

There were three permanent remount depots in the United States when the war began in April, 1917,—one at Front Royal, Virginia, one at Fort Reno, Oklahoma, and one at Fort Keogh, Montana,—an auxiliary remount depot at Fort Bliss, Texas, and a purchasing headquarters at Kansas City, Missouri. When it became certain that the Army would need a large number of horses, some of the most celebrated

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horsemen and riders in the country offered their services as buyers. Some fifty of them were commissioned as captains in the Quartermaster Reserve Corps and sent to the various purchasing headquarters for short training in the proper types of horses and animals required by the Army. These buyers purchased a large number of excellent animals.

In addition to the three existing remount depots there were established thirty-three additional auxiliary remount depots and two animal embarkation depots. The horses purchased were shipped to the various remount depots and there trained and conditioned for army use.

It required a large number of officers and men to care for the remount establishment. Shortly before the armistice was signed there were approximately 400 officers and 19,000 enlisted men in the American remount service.

Thousands of American animals were shipped to the American Expeditionary Forces in France. Because of the lack of tonnage, there were no animal shipments between March 26, 1918, and August 11. Between the declaration of war and March 26, 1918, a total of 30,329 animals were shipped abroad, and in the August 12-November 30 period 37,619 animals crossed the Atlantic, making a total of 67,948 American horses and mules sent to the American Expeditionary Forces.

The total expenditures of the Army, both abroad and at home, for horses and mules during the war period was $115,957,000, divided about half and half between the United States on the one hand and France, England, and Spain on the other.

The largest remount depot developed during the war was located at Camp Jackson, Columbia, South Carolina. This depot had a capacity of about 10,000 animals, and its construction cost was about $300,000. Soon after the armistice was signed, when it became evident that animals would no longer be needed, thousands of horses and mules at the different remount depots were sold at auction, the auction sales drawing large crowds of buyers.

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From French .
From Spanish .
From British .
In United States .
Private mounts
Young horses .
Total purchased ary 1, 1919

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Horses:
Cavalry .
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Grand to

STORAGE

The problem of storing army supplies became great only after hostilities had ceased. Before that time supplies were going through the warehouses and to the ships at the deep-water ports so rapidly that there was no backing up of the tide of them in the vast warehouse facilities that had been provided as a war measure. But as soon as the armistice was signed and the Army no longer grew in size, but rapidly diminished as men were discharged, the manufacturing operations under way, necessarily continued for a time on a scale which had been developed in preparation for an Army nearly double the size of the one that existed on November 11, 1918, soon began filling up the warehouses.

The operation of the Jeffersonville, Indiana, general supply depot was typical of the procedure at all the quartermaster depots. During the war the Jeffersonville depot procured for the Quartermaster Corps of the entire Army all horse-drawn vehicles and harness, and such items as barrack ranges, field ranges, and ovens, pack-train equipment, and other supplies. The war deliveries began at Jeffersonville in the late summer of 1917. Receipts soon outgrew storage space. Adjoining lands were leased; and supplies, covered by paulins, were stored in the open. This early period of the war, prior to the spring of 1918, was a back-up period at all the warehouses, for supplies were produced faster than men were trained and transported to France. In the late spring of 1918 Jeffersonville began making heavy shipments of supplies overseas, and from then on shipments exceeded receipts. For three months before the armistice was signed the Jeffersonville depot's shipments averaged sixty carloads a day and its receipts about twenty-five carloads.

After the armistice was signed, Jeffersonville was designated as the depot for the storage of all surplus horse-drawn vehicles and black harness therefor. Extensive temporary storage sheds were erected. Inbound shipments increased to about eighty cars a day. The depot stored 4,000 rolling kitchens of the trailmobile type, these kitchens being packed in boxes,

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each package weighing about 4,300 pounds. The piles of boxes were each 45 feet wide, 30 feet high, and 1,000 feet long. Corrugated-iron roofing was placed on the sides and tops, thus forming waterproof buildings. Crated automobile trailers, weighing about 9,000 pounds a crate, were handled in the same manner. Wagons were stored in galvanized-iron warehouses, each one capable of receiving 2,500 wagons, without wheels. Wagon wheels were stored in specially adapted sheds. Automobile trucks were stored in specially constructed sheds. These trucks were mainly Nash Quads, four-wheel-drive trucks, and G. M. C. ambulance chassis. These chassis were stored on end, resting on the bumpers. The engines of all trucks were well oiled and the magnetos covered with waterproof material.

As the supplies backed up into the warehouses, it became necessary for the Army to know where it stood in the matter of property; and a complete inventory was ordered, there having been no time to take stock during the hurry and bustle of the war period. This inventory in itself was an enormous undertaking. To prepare for it the quartermaster training school at Camp Meigs, D. C., was completely transformed into a school for training experts for taking inventories. A standard scheme was worked out. The experts, after being trained in the standard method, were sent out into every zone in the country as instructors. In each zone they convened the so-called "town meetings." The town meeting was made up of army storekeepers from each depot, post, camp, and station in the zone—any place where army supplies were stored. These representatives were schooled in the inventory method and then sent back to their stations with instructions to start the inventory on December 31, 1918. The next operation was to organize an inventory factory in Washington as the consolidating point for all the inventories in the United States. Some idea of the number of articles which Uncle Sam accumulated as a result of the war may be gained from the fact that the inventories received in Washington filled 40,600 sheets of paper, each the size of an ordinary large letterhead, with typewriting,

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single spaced. To take the inventory it required in Washington a force of approximately 100 officers and 400 civilians, and there were probably over 10,000 officers and men engaged in the entire operation throughout the country. The inventory was undoubtedly the largest ever taken.

Before the war the standard items of army supplies had been 20,000 in number. The inventory, in the consolidation of its figures in Washington, disclosed the fact that at the beginning of the year 1919 there were 120,000 standard items, many of which stood for large quantities of individual pieces. A catalogue, or standard nomenclature list, of supplies, comprising 120,000 items, was then prepared, to establish throughout the United States one language of supply for all items stored, distributed, and issued under the direction of the Director of Storage.

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CHAPTER XXXII

VEHICLES

THE motor truck in 1914 literally saved the world from German domination. In August when the gray tidal wave was inundating Belgium and sweeping on toward the boundaries of France, it was the London omnibuses that carried the "contemptible little army" of the British from the Channel ports to Mons, where they stayed the German onrush long enough to allow France to collect her armed strength. The shocked English-speaking people could with difficulty credit their senses as they beheld the spectacle of humdrum busses, symbols of peaceful transit in a modern metropolis, flaunting so incongruously their gay advertisements amid scenes of carnage and destruction.

Again and again in the exciting weeks that followed, motor transportation, even of the makeshift sort, was to demonstrate its value to the military commanders. The Germans alone seemed to have fitted the motor-driven vehicle properly into war plans. That first astonishing advance upon French soil was made possible largely by the efficiency of German trucks in carrying German soldiers forward from the railheads. Then in early September came Von Kluck's thrust toward Paris, which had so nearly succeeded except for the French division that moved on the night of September 8-9 in taxicabs.

In 1916 the German attack upon Verdun destroyed at the outset that stronghold's railroad supports, except for one weak and insufficient line. Yet the motor trucks and the splendid national highway that paralleled the railroad line from Bar-le-Duc to Verdun enabled the French to make good their defiant "*On ne passe pas!*" And in 1918, after the enemy had struck his supreme blow vainly, the motor transportation of

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the Allies, now highly organized and developed, enabled the Supreme Command to repeat on a grander scale what the German himself had done in 1914 and to overwhelm the enemy with fresh troops at the points where he was weakest. Motor transportation gave to armies a mobility such as land forces had never attained before.

What was the American Army doing with motor transportation in the half dozen years prior to 1917? The nation foremost in the production of motor vehicles was last to give scientific motor transportation to its Army. Beginning in 1904, there had been some sporadic study of the military truck transportation needs, but when the Army had to send an expedition after Francisco Villa in Mexico in the spring of 1916 it found itself entirely unprepared in transport facilities for the work ahead. Mexico refused us the use of her railroads, and to have seized them would have been an overt act of war, a thing we wished to avoid. Therefore the Army was thrown back upon its vehicular equipment, upon its wagon and pack trains; for it possessed but few motor vehicles. It was faced with the necessity of extending a rapidly lengthening line of communication over hundreds of miles of desert and mountain trails and to send over that line thousands of tons of supplies. The faithful army mule had given valiant service in the past, but he was unequal to such a task. The Quartermaster Corps, charged with the duty of providing army transportation, sent out an appeal for motor trucks.

Some of the leading truck manufacturers of the United States responded, and in a brief time the Army at the Border found itself equipped with about 2,500 motor trucks. The expedition organized seventy truck companies, each with an equipment of thirty-three trucks. The Army could not find in its own ranks enough drivers to man the trucks, and therefore they were sent into Mexico with civilian drivers. As rapidly as possible thereafter these companies were converted into military units with uniformed *personnel*, and they formed the nucleus of the great motor transport fleet which we were to bring into existence after 1917.

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Service at the Border thoroughly tested out the trucks and taught the Army some lessons about motor transportation. Chief of these lessons was the need for sharp standardization in the types of trucks used—a lesson, however, that was to be forgotten in the early months of the war with Germany, when our competing corps bought almost any motor vehicle that would carry a load at all.

In 1914, with the spectacle before our eyes of the use of motor trucks by the armies fighting in Europe, the Society of Automotive Engineers formed a committee to aid the War Department in the motorization of its supply trains. The Government took advantage of this offer at the time of the trouble with Mexico and profited by the expert advice of the trade in its purchases. Thereafter the manufacturers studied the operation of army trucks in the field and conferred with the War Department from time to time, so that early in 1917 the Quartermaster Corps was able to revise its specifications for trucks.

At this time (it was in May, shortly after the declaration of war) the Quartermaster Corps divided its truck requirements into three classes known as AA, A, and B, a classification that continued in use throughout the war. Class AA trucks were the smallest, having capacities ranging from 1,500 pounds to one ton. Class A trucks varied in capacity from one and a half tons to two tons. Class B trucks had carrying capacities ranging from three tons to five tons. These were standard classes for ordinary Q. M. freighting work, but other branches of the Army bought trucks of several other classes—ambulance chassis, passenger cars, and the four-wheel-drive 2-ton to 3-ton trucks, later known as Class T trucks. All corps made heavy purchases of motorcycles, side cars, bicycles, and truck trailers. All these vehicles had important uses quite outside the uses for the AA, A, and B trucks of the supply service.

In its specifications for trucks of the two major classes the Quartermaster General embodied the conclusions reached by army officers and by engineers lent by the truck manufacturers who had studied the truck question at the Mexican Border. In

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general the army specifications called for trucks with larger engines than those usually installed in commercial trucks of the same sizes, larger radiators, four-speed transmission instead of the usual three (first speed being unusually slow), maximum ground clearance, demountable tires of standard sizes and specifications, larger gasoline tanks, electric lighting systems, springs of extra-quality alloy steel, three-point engine suspension, and other technical requirements. All these specifications were drawn to meet the hard and unusual conditions of service which an army truck must undergo.

This was leading toward standardization, but it was not yet standardization, since any builder making trucks that met the specifications might supply them to the Government. The needs for standardization were obvious. One must think of the administrative branch of the Army, as it existed in 1917, as a group of almost independent bureaus and corps, jealous of their powers and prone to reach out and seize functions that did not properly belong to them. In 1916 the Quartermaster Corps was charged by law with the duty of supplying all transportation to the Army, even animal transportation, except the transportation of artillery and of engineering pontons. The Corps even bought the army ambulances. But in the emergency of the Mexican campaign the Medical Corps, the Engineers, the Signal Corps, and the Ordnance Bureau all stepped out and began to buy motor vehicles. At first, of course, they bought only special vehicles adapted to their peculiar service needs; but later they went into the market for cargo trucks, passenger automobiles, and motorcycles.

This innovation brought no serious results, because the total number of vehicles purchased was comparatively insignificant. As it was, however, the Army used 128 different makes and models of motor vehicles at the Mexican Border. The upkeep of these machines meant, of course, that the Army had to buy 128 different sorts of repair parts. As long as the machines were few in number this necessity brought no particular problem.

Each of the above-named bureaus managed to cling to its

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function of buying its own motor equipment, and each carried the function into the war with Germany, when all began buying motor vehicles in tremendous quantities. The Air Service separated itself from the Signal Corps and assumed that it, too, was authorized to purchase trucks and automobiles. Each of the six services developed a motor transport division. Single combat units at the front had to look to as many as five separate sources for motor equipment. To make matters worse, the A. E. F., as soon as it stepped on European soil, began buying motor vehicles of foreign make; so that at one time the American Army was using 294 different makes and body types of motor vehicles, 213 of these of American manufacture and the rest foreign. No administrative genius at headquarters could hope to maintain an adequate supply of parts for the repair of these machines, even if spare parts had been plentiful.

The whole structure fell of its own weight. It failed in the supreme test, the test on the field. The A. E. F. acted first by consolidating all motor transportation under the direction of a single Motor Transport Corps. The Army in the United States followed this action some weeks later. The procurement of vehicles, however, was later vested in the Purchase, Storage, and Traffic Division of the General Staff, the Motor Transport Corps being charged only with the duty of operating the equipment. This action brought once more under a single head the supply of all army vehicles.

Business sense rebelled at the confusion in the Army's motor equipment. The solution was obviously the limitation of vehicle types and the standardization of the vehicles of each type. Standardization would not only simplify the problem of upkeep and repair in the field, but it would also enable the War Department to purchase extra parts in large quantities at a great saving in cost and total manufacturing time. Enthusiasts thought it would be possible to specify a standard list of types and sizes for army motor vehicles and to create one standardized vehicle in each type, permitting the purchase and use of no others. Subsequent experience and study, both before and after the armistice, convinced the Army's motor experts that,

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because of conditions in the automobile trade, no such severe limitation was practicable; but it was their conclusion that a minimum of fifteen makes and types and a minimum of forty models within these types would take care of the Army's every transport and special service need, even in such a campaign as that in France. The American Army in the World War used about seven times that number of models.

Long before this conclusion was reached—in fact, shortly after America became a belligerent—the Quartermaster Corps set forth to standardize its vehicles. It should be remembered that at that time the Corps was no longer buying ambulances, ordnance trucks, or other special service vehicles, and that it had only its own needs to consider. Yet those needs were greater than those of any other organization except, perhaps, the Ordnance Department; for the Quartermaster Corps had the duty of maintaining the supply of food, clothing, fuel, and other principal items of army consumption, in volume and weight outclassing any other kinds of military supplies except ammunition and other ordnance materials. The Corps was buying trucks in three major sizes, light, medium heavy, and heavy, called respectively Class AA, Class A, and Class B. In the rush to get motor equipment to France it was impracticable to create new standardized vehicles for all the required sizes in these three classes. The motor experts in the Department therefore decided to pick out the size that should be most needed in maintaining the supply service in France and to standardize a vehicle of that size. This would not entirely clear up the truck situation, but by simplifying the problem of maintaining the truck most commonly used by the Expeditionary Forces it would go a long way toward it.

It was decided that the most useful trucks in the A. E. F. quartermaster supply service were those of the heavy B class, three to five tons in capacity. Accordingly the motor experts in Washington created especially for the Army a new standardized heavy truck known as the Quartermaster Standard B. The creation of this vehicle attracted the attention not only of the truck industry, but of practically the entire United

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States as well. It was almost as well known as that other famous standardized machine produced by the Government during the war, the Liberty aviation engine.

The development of the Standard B truck was a most interesting operation. Early in the summer of 1917 the Quartermaster Department set aside a fund of $175,000 to pay the costs of experimentation, testing, designing, and drawing the specifications for the proposed vehicle. On August 1, 1917, a committee of fifty of the leading motor-truck engineers of the country assembled in Washington to make the new design. These men, together with a number of army officers expert in the same field, acted as a jury; and to them the truck manufacturers and parts manufacturers brought members and elements of truck construction which they desired to have incorporated in the standardized machine. These devices the technical jury tested competitively with an eye both to the severity of the field service to come and to the adaptability of each part to rapid fabrication with the other parts chosen. Thus, by a process of elimination, gears, transmission, engine, differential, axles, bearings, and the hundreds of other parts that go into the manufacture of a complete vehicle were selected. The ensemble was a composite of the best that the combined American truck industry could put into a vehicle for the service required. On October 19, 1917, the first two Standard B trucks reached Washington, after an overland journey that engaged the notice of the United States, and were formally and publicly presented to the War Department. In their tests these two machines did everything that had been expected of them.

The production of Standard B trucks was placed in the hands of a group of practical manufacturers called to Washington on that account. At the head of this group was Mr. Christian Girl, president of the Standard Parts Company, of Cleveland, Ohio, and with him were associated Messrs. John Younger, of the Pierce-Arrow Company, Buffalo, New York; James F. Bourquin, of the Continental Motor Company, of Louisville, Kentucky; Percy W. Tracy, of the Premier Motor

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Company, Indianapolis, Indiana; Walter S. Quinlan, of the Maynard H. Murch Company, Cleveland; Guy Morgan, of the Mitchell Motors Corporation, Racine, Wisconsin; J. G. Utz, of the Standard Parts Company, Cleveland; G. W. Randels, of the Foote-Burt Company, Cleveland; and A. G. Drefs, of the Miller-Franklin Company. These gentlemen acted as a manufacturing committee for the Government. They provided for the manufacture of the parts and supplied the parts to the concerns chosen to do the assembling. The designing of a standardized truck enabled the Government to take a large part of the automobile and truck industry and turn it into what was virtually a single manufacturing establishment for the production of this one truck. It was the policy to provide three or four sources of supply for each part used, in order not to delay the whole enterprise in the event that any one parts maker experienced factory difficulties; and as a result of this policy the contracts for elements of the standard truck went to some 150 parts manufacturers. Twenty leading truck factories were designated as assembling plants.

By the early spring of 1918 the manufacture of Standard B trucks was booming, and the contracts piled up until eventually the orders placed called for a total production of nearly 43,000 of them. Close to 10,000 were produced before the armistice, and nearly 8,000 of these were shipped overseas. The production after the armistice delivered 7,641 more to the Government.

Though the Standard B was the only specially designed army truck that came into production and use during the period of hostilities, the War Department continued its efforts in this direction, eventually creating a Standard AA and a Standard A truck, both of them assemblies of parts standardized because of their special adaptation to the service required. Neither of these trucks was put into production, simply because the needs of the Army could not be deferred until the factories could build up a supply of the vehicles. Five experimental Standard A trucks, however, were produced for testing. After the armistice these five machines were turned over to

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the Post Office Department, where they have performed with remarkable efficiency. The Ordnance Department also created the design of a four-wheel-drive Class T truck, calling the vehicle the "Militor," and built five of them experimentally. Two of these trucks journeyed from Washington to San Francisco in the Transcontinental Convoys of 1919 and 1920, successfully serving as tractors in the rough going. After the armistice the Army bought seventy-five Militor trucks for the artillery.

The lack of time stood in the way of manufacturing specially designed vehicles for each class in use; yet, even under the war conditions, much could be done to simplify the vehicle supply and upkeep. The expedient thing to do was to test the established commercial makes, determine what ones would stand up to the service best, and adopt these as standard, even though it meant more than one standard vehicle in each class. The various bureaus that had been buying motor vehicles were working in this direction in 1918, when war department orders took all vehicle procurement powers from the six bureaus and consolidated them in the newly established Motor Transport Service. Later these procurement powers went to the Director of Purchase of the General Staff Division of Purchase, Storage, and Traffic, and the Motor Transport Service became the Motor Transport Corps, thereafter charged with the operation only of the Army's motor equipment.

Simultaneously with these changes came the establishment of a standardization board, whose duty it was to provide standardized machines in each class of motor equipment. This board followed the policy of adopting known makes of machines in the various classes and designating them as standard. On this board were represented the various departments and services which used motor transportation; and therefore no army interest was overlooked in the deliberations. The board designated the standards as follows:

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Class	*Capacity*	*Make*
Motor Cars	Light	Ford
Motor Cars	Medium	Dodge
Motor Cars	Heavy	Cadillac
Ambulances	Light	Ford
Ambulances	Heavy	G. M. C.
Trucks, Light Delivery	600 pounds	Ford
Trucks, Light Repair	1,000 pounds	Dodge
Trucks, Class AA	¾ ton	G. M. C.
Trucks, Class A	1½ tons	White
Trucks, Class B	3-5 tons	Standardized
F. W. D. Trucks	2-3 tons	(None)
Motorcycles		Harley-Davidson
Motorcycles		Indian
Side Cars		Harley-Davidson
Side Cars		Indian
Bicycles		Westfield

The reader should understand that in standardizing a motor truck the War Department standardized the chassis only. Upon the standardized chassis might be mounted bodies of various types, to serve different purposes. The Standard B truck, for instance, served variously as a mobile machine shop and for carrying special signal corps apparatus, aside from its common use as a quartermaster cargo carrier; the G. M. C. Class AA chassis was suitable for carrying an ambulance body; and so on.

In designating certain known and established makes of motor vehicles as standard, the War Department worked on the theory that it would place contracts for the production of these machines, not only with the concern that had been making them commercially, but with any other manufacturer to whom the Department cared to turn. In that event the original maker must turn over to the other contractors sets of his drawings and specifications. In practice, however, this theory was not carried out to any considerable extent. Contracts for the production of the G. M. C. AA truck went to a dozen motor car factories besides the Pontiac factory of the General Motors Truck Company, but these were mostly companies subsidiary to the General Motors Corporation. The Peerless Motor Car

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Company, and the Winton Company, of Cleveland, contracted to build White Class A trucks. Other standard makes were produced exclusively by the commercial makers, except that the Westfield bicycle, adopted as the military standard, was produced by the Great Western Manufacturing Company, of Laporte, Indiana, and the Davis Sewing Machine Company, of Dayton, Ohio, as well as by the Westfield Manufacturing Company, of Westfield, Massachusetts.

In the summer and fall of 1918 the needs of the A. E. F. and of the Army in this country for motor transportation were such that it was impossible to follow the standardized schedule and still provide adequate equipment. Consequently the standardization board approved, until such time as the production of the standard vehicles could be expanded to fulfill the demand, other makes of trucks to serve as temporary substitutes for the standard vehicles. In designating these makes the board considered what makes were already in widest use by the A. E. F. Thus the Commerce 1-ton and the White 1-ton trucks were approved in substitution for the standardized G. M. C. Class AA truck; the Packard, Mack, Riker, Pierce-Arrow, and other heavy trucks for the Standard B truck; and so on. Even with such latitude granted, it was impossible to supply both the home and the overseas armies with trucks standardized or approved as substitutes; and therefore, since the upkeep problem was simpler at home than abroad, it was ordered that only trucks of the standard and approved substitute classes should be shipped overseas, and that the excess domestic military demand should be met with trucks not in these lists. The result was that the Army bought practically every established American make.

Such was the history of army motor transportation. In 1917 and 1918 nearly 100,000 trucks and chassis, about 15,000 ambulances and 18,000 passenger cars, 65,000 motorcycles with side cars, and 68,000 bicycles were delivered to the Army. The contracts originally made called for the delivery of approximately 200,000 trucks and 38,000 passenger cars. About December 1, 1918, cancellations were made on contracts to

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Photo from Quartermaster Department

STORAGE OF CHASSIS

Photo from Hart-Parr Company

MAKING STEEL WHEELS FOR ARTILLERY TRUCKS

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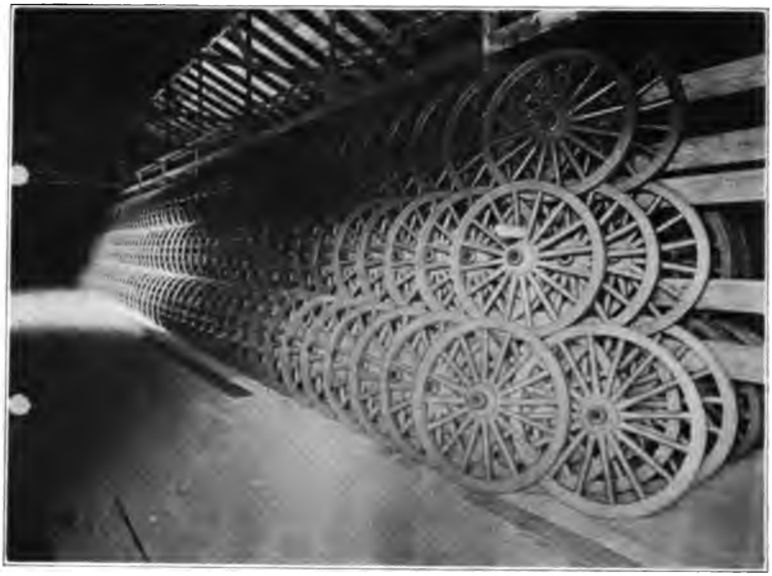

Photo from Quartermaster Department

WAR-BUILT WAGON WHEELS IN STORAGE

Photo from Watson Wagon Company

ARMY WAGON BODIES READY FOR SHIPMENT

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the extent of approximately 80,000 trucks and 20,000 passenger cars. After the armistice there were approximately 150 passenger cars and 31,000 trucks and chassis upon which the work had progressed too far for cancellation, and these were delivered.

In spite of this production the A. E. F. was still inadequately supplied with motor transport facilities. After the rush of troops to France began in the late spring of 1918, the curve of A. E. F. truck requirements left far beneath it the curve representing truck capacity in the A. E. F. The fault, however, was not that of the manufacturing industry. The docks on this side were crowded with trucks at practically all times. That more were not sent to France was due to the lack of ships. In all, about 50,000 American motor trucks were shipped to the overseas forces.

Even so, the failure to meet the truck requirements of the A. E. F. occurred only because we placed our truck requirements so high. In November, 1918, the A. E. F. had twice as many motor vehicles to the million men as the French Army had. Comparatively, the American Army in the field was well equipped indeed.

HORSE-DRAWN VEHICLES

Although the purchases of horse-drawn army wagons, amounting to approximately $21,000,000 in value by the date of the armistice, seem small in comparison with the enormous requisitions of motor vehicles, they were enough to engage practically the entire wagon-making industry of the United States and to bring in some of the largest furniture factories and automobile wheel makers as additional sources of supply. It was seen at the outset that it would take every bit of the wagon-making capacity of the country to supply the Army's needs. The gasoline motor was unable to oust the war horse completely from his time-honored occupation. For many sorts of military transportation it was impossible or impracticable to use mechanical power. The Army had to have escort wagons, combat wagons, drinking water wagons, dump wagons, buck-

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boards, ration carts, horse ambulances, and other indispensable conveyances, all of which were horse drawn, besides a goodly equipment of carts to be pushed or pulled by human hands. Contemplating the purchase of such vehicles by tens of thousands, the procurement officers in Washington did not attempt to apportion the work themselves, but called to their assistance the foremost representatives of the wagon-making industry. Messrs. R. V. Board, of the Kentucky Wagon Company; A. B. Thielens, of the Studebaker Corporation of America; E. E. Parsonage, of the John Deere Wagon Company; and R. W. Lea, of the Moline Plow Company, became an advisory committee which thereafter assisted the Government in purchasing horse-drawn vehicles.

One outstanding innovation in wagon manufacture resulted from the war pressure. In his ordinary work no wagon maker would think of putting into vehicles hickory or other woods that had not seasoned and weathered under long exposure to sun, wind, and rain. The Army's very first order for escort wagons, however,—for 34,000 wagons, which, with spare parts, were the equivalent of 50,000 wagons,—exhausted the visible supply of air-dried wagon lumber, making it certain that, unless new processes were adopted, the army wagon program would languish. Consequently the industry turned to kiln-drying. But the wagon-making industry possessed no equipment of kilns adequate to such a project. The War Department therefore agreed to pay half the cost of dry-kilns, reimbursing the manufacturers for their outlay gradually by adding $10 to the price of each wagon delivered and a similar amount to each payment of $185 for spare parts. Even with kiln-drying it required six months to prepare a log for the saws; yet so well did the industry respond to the Army's call that it turned out nearly 90,000 vehicles before the armistice. This output included several classes of vehicles specially designed after the declaration of war. To make this record the industry turned to the makers of automobile wheels for large quantities of wheels for army escort wagons. The War Service Committee of the Furniture and Fixture and Light Wood

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Industry arranged for the furniture makers of the United States to produce 75 per cent of the spare parts for the new army horse-drawn vehicles. In all, about 250 manufacturers engaged in the enterprise.

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Production of Horse-Drawn Vehicles

	Number ordered between April 6, 1917 and Nov. 11, 1918	*Value of orders*	*Quantity delivered up to Nov. 11, 1918*	*Quantity shipped overseas*	*Value of quantity shipped overseas*
Commercial vehicles . . .	181,077	$41,247,911	89,024	28,918	$7,247,522
Spare parts	......	39,690,255	.....	.....	2,551,642
Total	181,077	$80,938,166	89,024	28,918	$9,799,164

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CHAPTER XXXIII

MEDICAL SUPPLIES

LEST it be thought that the American Army was dependent in any way upon private contributions for its hospital facilities and surgical supplies, it should be recorded that the Government, during the period between April 6, 1917, and November 11, 1918, placed contracts for medical supplies amounting to $424,761,031. Contract terminations after the armistice was signed amounted to $56,000,000. The remaining $370,000,000 represents approximately the cost to the United States of medicine, surgical instruments and dressings, ambulances, hospital furniture, equipment and supplies, and dental and veterinary supplies for the war. This was considerably more money than was contributed by the American people to the American Red Cross, a great part of whose funds went to the relief of civilian populations in Europe and to other war charities. The Government, with billions of dollars to spend, could well afford the few hundreds of millions necessary to give American soldiers the best possible hospital attention. It accepted gifts of medical and surgical supplies, ranging from gauze bandages to fully equipped motor ambulances, as the offerings of a people whose hearts overflowed with love and gratitude to the American soldiers and who took this means of showing their solicitude; but the Government was in no sense dependent upon these donations.

Before 1914 four-fifths of all surgical instruments used in the United States were imported from Germany. This country was practically dependent upon Germany, too, for many of its most important medicines, including the potassium salts and such drugs as digitalin, salvarsan, and atropin. To a certain extent we had been developing substitute sources of supply in the United States for these indispensable commodities in the

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months between the outbreak of the Great War and the date of our participation in it; but the raising of a vast army and the project of sending this army to the bloody battle fields of France created an American demand for medicines and surgical instruments beyond anything ever known in the United States. Yet, through the coöperation of manufacturers and the officers of the Medical Department's general purchasing office, which on November 15, 1918, was incorporated in the office of the Director of Purchase and Storage, sufficient supplies were developed, not only of medicine, but also of surgical instruments.

The development of the production of medicines for the use of troops in the field was particularly notable. The important drug salvarsan, used in the treatment of syphilis, was a patented formula which had been furnished formerly by a single German manufacturer. In this country we produced arsphenamine as a substitute, gradually increasing the supply and constantly improving the drug until at length its toxicity had been so reduced that it equaled or even excelled the German product.

The facilities of American drug and tablet manufacturers were taxed to the utmost to supply the Army. For example, during the year 1918 a total of 46,000,000 quinine tablets was produced. One hundred and seventy-two million aspirin tablets were manufactured during the same period, and 835,000 pounds of calomel ointment, 45,000,000 iodine swabs, 10,-250,000 tins of foot powder, and 300,000,000 tubes of iodin-potassium. All other items of medicines, antiseptics, and disinfectants required by the Medical Department were increased in proportion. This production not only strained the facilities of the manufacturers of chemicals and drugs, but also called upon the glassware manufacturers for the necessary bottles and tubes in which to pack these medicines satisfactorily. Here again was an effort that required, in order to meet the demand, close coöperation between the trade and the Medical Department.

When it became evident that a declaration of war against

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Germany was imminent, the Medical Department proceeded to analyze the country's resources of medical supplies. These were disturbingly limited. The Allied nations had been making heavy and constant demands for these materials—so great demands that even the mobilization of such a relatively small number of troops as were centered on the Mexican Border put a severe burden upon the medical supply facilities of the country. The Council of National Defense took up the medical supplies problem at the outset. The various manufacturers sent their representatives to consult with the Surgeon General, and committees on surgical instruments, surgical dressings, medicines, and other important supplies were formed. These committees allocated among the various manufacturers the first emergency orders for these materials. The result was that the base hospitals at the thirty-two mobilization camps in 1917 were equipped in an amazingly short time. The New York Medical Supply Depot, which was then the largest purchasing agent, was called upon to supply five hundred hospital beds to each of twenty-two camps. This work was handled so rapidly that some of the shipments had to be held back to wait for the completion of the hospital buildings.

Perhaps the most difficult task was to determine what quantities of medical supplies would be needed for a given period. It is a comparatively simple matter to estimate the quantity of clothing necessary for a certain number of troops, or to figure what food they will require; but it is not possible to forecast the number of men who will be sick at a given camp at a specified time, nor is it possible to foretell the kinds of diseases or injuries. An epidemic of measles or mumps requires different treatment from an epidemic of influenza, and makes necessary the use of a different variety of medical supplies. Experience sheets of supplies actually used in the past formed the basis of our requirements schedules.

Eventually there was worked out a system of supply based on the initial requirements of the unit of 25,000 men in the Expeditionary Forces and the automatic supply of replenishment of this equipment. In this system use was made of

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the knowledge and experience obtained by the British and French medical forces during their nearly three years of warfare before America went in. Civilian experts in various types of medical supplies were brought into the organization to supply the wide range of specialized knowledge required in such a universal buying program as the Medical Department was about to conduct. Before the war the Army's purchases of instruments for oral and brain surgery, orthopedic supplies, Dakin outfits, and other special apparatus were practically negligible. During the war period these purchases amounted to millions of dollars. It can readily be seen, then, that the purchasing office had to possess more than a superficial understanding of the materials to be bought. Orders customarily went to the lowest bidders, with a careful review in Washington of all prices named in contracts. The inspection of material was an important phase of the work. This inspection was handled through the New York Medical Supply Depot, which called in as assistants the United States Board of Customs Appraisers at New York City. That corps of men had had long years of experience in inspecting and determining the value of surgical supplies, for most of these supplies in the past had come through the customhouse from foreign countries. The inspection of drugs was handled by the Medical Department's laboratories, the Army Medical School, and by the Bureau of Standards, which rendered valuable assistance in examining and testing samples. In addition the Medical Department maintained a corps of inspectors to travel from one factory to another, keeping in close touch with the progress and assisting in procuring raw materials and expediting deliveries.

The medical supplies were divided into the following classifications:

(a) Hospital equipment, such as beds, bedside tables, enamel ware, etc.
(b) Surgical dressings.
(c) Surgical instruments.
(d) Medicines, antiseptics, and disinfectants.

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(e) **Field supplies (chests and units for extended field service).**
(f) **Dental supplies.**
(g) **Veterinary supplies.**
(h) **Laboratory supplies.**
(i) **Motor ambulance supplies.**
(j) **X-ray supplies.**

The New York depot was entrusted with the purchase of miscellaneous hospital equipment and dental and X-ray supplies. The St. Louis depot purchased the veterinary supplies, and the field medical supply depot at Washington purchased the laboratory and field supplies. The motor ambulance supply depot, established at Louisville, Kentucky, purchased ambulances and ambulance spare parts. In appreciation of the necessity for a certain amount of coöperation where the purchase of similar articles by the various depots was concerned, the general purchasing office of the Medical Department was organized at Washington. This purchasing office bought all surgical dressings, surgical instruments and medicines, and such items as were used in the field, post, veterinary, and dental stations.

In fostering the production of surgical instruments in this country it was necessary for the Medical Department to educate in the manufacture of these instruments certain concerns which had been engaged in the production of similar devices. Men skilled and with long years of experience in the manufacture of instruments were sent to these factories to work out satisfactory processes with the forces there. It was necessary to recruit toolmakers, jewelers, and cutlery manufacturers in order to build up a sufficient supply of forged and finished instruments. Surgical needles, for instance, had never been made in this country, but had all been obtained in England. As a war measure the British Government placed this item on its list of restricted exports. After long and continued effort the general purchasing office developed American sources of supply of needles, and with remarkable success.

In one month we shipped sixty-five tons of surgical instruments to France. A few of the principal instruments, quantities purchased, and prices paid were as follows:

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	Average cost, each
1,301,476 hæmostatic forceps	$ 1.04
284,600 tissue forceps	.59
348,500 minor operating knives	.57
225,000 probes	.047⅞
309,548 surgical scissors	.741
2,102 general operating cases	159.55
3,400 small operating cases	45.30
10,000 instrument cases for officers' belts	5.28
300,000 enlisted men's belt cases	1.35

Each general operating case contained more than fifty instruments and the small operating case more than thirty instruments, and in these two items alone were more than 207,000 forgings, practically all handwork.

The quantity of surgical dressings used in peace times was relatively small, and the sources of supply had to be increased enormously. To do this the Government went out into the cotton goods industry and induced such concerns as curtain makers and manufacturers of waists and white goods to make bandages for surgical uses. The Government obtained the raw material, gray gauze, and turned it over to the various manufacturers for bleaching, cutting, sterilizing, and packing in the necessary cartons. Among other items, during the last year of the war a total of 12,000,000 individual dressing packets were purchased and 795,000 boxes of gauze bandages, 574,400,000 yards of bandage, 10,000,000 first-aid packets, and 108,000,000 yards of gauze. During the same period a total quantity of 3,814,000 pounds of absorbent cotton was also bought.

Among the miscellaneous items obtained were approximately 1,600,000 blankets, 258,000 litters, and over 1,000,000 clinical thermometers. The rate of output of clinical thermometers not being all that the Medical Department thought it should be, a large quantity of thermometers was obtained on mandatory orders.

The heaviest buying period during the war was between July 1 and November 30, 1918. The supplies purchased or ordered in that period were as follows, with their costs:

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Medicines, antiseptics, and disinfectants	$19,728,715
Hospital furniture and equipment	8,220,297
Hospital supplies, textiles	69,321,787
Hospital supplies, miscellaneous	1,808,465
Surgical instruments	6,576,238
Surgical dressings	75,762,383
X-ray equipment and supplies	2,466,089
Dental equipment and supplies	4,932,178
Laboratory equipment and supplies	2,301,683
Veterinary equipment and supplies	3,258,119
Motor ambulances and supplies	25,625,000

It is interesting to note that the purchases made in France for the Medical Department consisted mostly of large and bulky items, mainly hospital furniture and equipment, which, if transported from the United States, would have necessitated the use of considerable valuable cargo space. Foreign purchases were made primarily to save ship space, and not because of any shortage or failure to function in this country.

Although America is famous throughout the world for her dentists and dentistry, the participation of this country in the war created a demand for dental supplies that the American manufacturing facilities of 1917 were unable to fill. For that reason it was necessary to extend the production capacity. The manufacturers in the trade rose to the occasion, and the Government was able to supply to the A. E. F. from the United States all dental materials required, the only purchases made in France being of exceedingly bulky apparatus. The total amount allotted for dental supplies for an army of 5,000,000 men in 1919 was $6,256,482. During the five months between July 1 and November 30, 1918, the dental purchases amounted to approximately $5,000,000.

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CHAPTER XXXIV

AMERICA'S INDUSTRIAL RÔLE

THE reader who has followed us to this point has before him the picture of the nation's industry at war; the whole teeming effort in its main outlines, its myriad ramifications, its boundless activity, its ten thousand enterprises, its infinite toil, its hosts of workers, its wonders of scientific achievement, its attainments, even its failures; in short, that humming complex of work, planning, ambition, disappointment, triumph, shortcomings, ability, and driving force which was a mighty people concentrated with all its powers upon a single objective. It remains now to describe the place occupied by this effort in the whole strategic plan of the war against Germany.

We did not go into the struggle as if we expected to fight a single-handed war. Whatever we did, either with military *personnel* or with munitions, we did with reference to what the nations associated with us were doing or could do in the same respects. The whole plan was coördinated more or less perfectly, and international understandings and agreements touched and influenced even the most trivial of our enterprises. The reader who has in mind the purport of the record set down on the preceding pages is now prepared to comprehend the force and extent of the international coöperation in the war and to judge how well America played her part in the general scheme. Let us go back and review the history of the agreements with our co-belligerents.

For many months before America came into the struggle, England, France, and Italy had been engaged in grappling with the scientifically organized forces of German military autocracy. The World War had become a conflict of materials almost as much as of men. All participants had mobilized their

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industrial resources in a manner and to an extent undreamed of in times of peace. The Allies had marshaled all available raw materials and factory production in their own lands, and still they faced colossal deficits in supplies for their military programs. They had been forced to reach out into the markets of the world to meet these deficits. They had come to America and placed huge orders for raw materials and finished products.

The normal capacity of America's peace-time production had been insufficient to meet their overwhelming needs. In August, 1914, the total factory capacity in the United States for the manufacture of powder was 6,000,000 pounds a year. In April, 1917, under the stimulation of orders placed by the Allies, the capacity had been increased more than sixty-fold. England, France, and Italy were taking this entire production and asking for more. They had absorbed our entire output. A huge stream of materials, supplies, and ammunition was flowing steadily from America to the front-line trenches in France. The Allied governments had molded their military programs in reliance upon the continuation of this source of supply. Their troops were on the front and in contact with the enemy. Failure of supply meant disaster. The flow of materials from America to the armies in France could not, under any circumstances, be interfered with or curtailed. This fact was promptly recognized by the United States, and the Allied governments were assured that America's military program would be formulated and performed without interference with the Allied programs of supply from this country. America's industrial contribution to the war was to be over and above the industrial contribution to the Allies then being made by our individual producers. This fundamental plank in the Interallied platform of coöperation was laid down at the very outset of America's preparation, and it was strictly adhered to until the end of hostilities.

A comprehensive coöperative plan for America's industrial participation in the war remained to be worked out. A survey had to be conducted of the new partner's strength and weakness

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in supply. An ascertainment had to be made of what the Allies could give to the new partner, and what they must receive from her. This was done by the Interallied Munitions Council sitting in Paris, by the foreign missions in Washington in conference with the War Department, and by the Allied war ministries and General Pershing abroad.

An analysis of the facts of the situation disclosed that:

A. The world over—

(1) There was a critical shortage of ocean tonnage, which promised to become more critical as time passed, on account of the success of German submarine operations.

B. In France and England—

(1) The output of factories was being seriously curtailed and limited by lack of raw materials and semi-finished products.

(2) If an adequate supply of raw materials and semi-finished products could be made available, the factories had a substantial surplus manufacturing capacity which could be placed at the disposal of the United States.

C. In the United States—

(1) A surplus of raw materials and semi-finished products for transport to France and England could quickly be made available.

(2) It would be impossible, within less than a year, to build up additional manufacturing capacity in the United States sufficient to supply a large army.

The lack of ocean tonnage was recognized by all as the crux of the problem. France, Italy, and the United States had comparatively little merchant tonnage. England's vast tonnage was suffering rapid depletion by submarine losses and was totally inadequate to Allied needs. Ships were the biggest single deficiency in the Interallied program. The coöperative industrial program of the Allies and the United States had to be geared into the shipping problem. To do this the determination of what materials should be shipped from the United States had to be decided, first of all, on the basis of what economies could be effected in shipping space. If raw materials

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for aircraft occupied less cargo space than the finished product, the maximum utilization of available tonnage demanded the shipment to France of these raw materials, to be made into the finished product there. If, on the other hand, finished nitrocellulose powder for artillery shell propellants, or finished picric acid for artillery shell explosives, occupied less cargo space than the raw component materials used in their production, the shipping shortage demanded manufacture of these explosives and propellants in the United States. Not a single ship could be freighted with an extra pound or cubic foot of cargo which by any effort could be saved.

The French Mission in the United States early recognized this fact and urged the manufacture in the United States of picric acid to be used as explosive in 75-millimeter and 155-millimeter shell, pointing out that the finished product occupied but one-nineteenth as much cargo space as the raw materials. General Pershing recognized the point, and in August, 1917, cabled as follows:

> A joint French-American commission has examined the question of the production in France of powders and explosives and reports as follows: France must import by December 4 the greater part of the raw materials used in the manufacture of powders and explosives. The weight of raw materials required is 10 to 20 times the weight of the finished product. The shipping situation is such that by December the output of France will be limited by the amount of raw material produced in France or easily obtainable. . . . The present outlook is that in December the French output will not be more than half of the present output. To avoid calamity the United States must not only furnish powder and explosives for all of its own forces but must supply about half of the French requirements. It is therefore recommended: (A) that the United States Government furnish all powders and explosives needed for present contracts with French Government; (B) that the United States Government prepare to furnish by December 300 tons per month of explosives and 200 tons per month of powder for French consumption; (C) that study be immediately commenced for the purpose of adapting American powders to French cannon of different types, this study to be made both in the United States and in France by competent experts; (D) that the French Government put at the disposition of the American Government competent experts both in the manufacture and use of these powders in the guns. . . .

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Subsequent computations made on this side of the ocean indicated that, so far as picric acid and other explosives were concerned, this ratio between the bulk of raw materials and that of the finished product was too great, but in principle these computations did not affect the desirability of shipping the finished product rather than the raw materials.

Again, General Pershing cabled to the Chief of Staff in the United States urging the purchase of completed artillery, artillery ammunition, and airplanes abroad, in order that "saving of tonnage" might be effected, and pointing out the saving of cargo space which would result from the shipment to France of raw materials instead of finished products. He said:

Following is comparison in tonnage of the principal manufactured articles of ordnance obtained in Europe and the replacement in raw materials contracted for the same. All tonnage ratios shown are in favor of raw materials:

Field-artillery guns	1 to 7½
155-millimeter howitzers and ammunition	1 to 1¼
8-millimeter ammunition	1 to 3⁶⁄₁₀
Trench mortars	1 to 12½.
Grenades	1 to 4
In airplane production:	
Packed airplanes, in weight	1 to 2
Packed airplanes, in cubic capacity	1 to 2½
Packed airplanes in area covered by boxes on board ship	1 to 9

In the above comparison for the ammunition item, finished explosives are regarded as raw materials.

The Interallied Munitions Council, sitting in Paris and containing among its membership the best military and industrial brains at the command of the Allied cause, including General Pershing, General Robertson, chief of the imperial general staff of Great Britain, and General Foch, then chief of the general staff of the French Army, came to the same conclusion, and General Bliss transmitted its findings in a memorable cable, a part of which was reproduced in the introduction to this book. Every mind was in accord. Tonnage must be

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saved. It could be saved, and in vast amounts, by calling on the United States to supply the raw and semi-finished materials, and on the French and British war factories to utilize these raw and semi-finished materials in the manufacture of the finished products.

But could this solution of the vital shipping question be dovetailed into the industrial situations of the various nations concerned? Could the United States supply the essential raw and semi-finished materials in quantities equivalent to the amounts consumed in the manufacture of the finished product? Did the French and British factories, with these materials laid down in their yards, have available a sufficient manufacturing surplus to supply the needs of their own armies and also to produce in part for the armies of America? The foreign missions were in Washington. They knew intimately the economic and industrial situations in their respective countries; they knew the military plans of their general staffs; they knew in what respects their programs of supply for their armies in the field needed assistance, and in what respects these programs could be met or exceeded. With this information available, they were prepared to furnish the answer as to the manufacturing capacities of Allied Europe.

The British War Mission in Washington communicated to the War Department a cable from the British minister of armament, setting forth the position of the British Government on reciprocal supply:

The British Government is willing as far as possible in matters of urgency to manufacture for use of the Americans any products necessary to the more speedy equipment of the Americans that the Americans consider they can obtain in England more promptly or better than in the United States. Furthermore, the situation as to manufacture of steel products is better than it has been. The British Government will help to its utmost ability without making actual and immediate replacement of raw material an indispensable condition when any order is given. On the other hand the general principle of replacements of raw materials as soon as possible should be observed. It has become more a question of furnishing supplies promptly to the Allies than a mere question of replacing what has been furnished American troops; in other words,

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the needs of the Allies should be considered as one, and England should manufacture for the Allies anything that is necessary or best got that way, and America should in the general interest of the Allies furnish as soon as convenient raw material to replace that used. . . .

Writing to Major General Crozier, Chief of Ordnance, the French high commission urged the placement in France of orders for artillery and artillery ammunition and pointed out the existence of surplus factory capacity available for their production. The commission summarized the industrial situation in the following language:

Even in such remarkable technical conditions as yours, it takes time to realize such a program, to organize manufactures and to have men to direct them. You will take less time than we did in France, where the output of big guns was not adequate to our needs before the end of 1916. But time—more or less—had to be an essential factor, so that after careful consideration, it has been found that the only plan to be carried out in order to supply the first American divisions with material on their landing in France was to avail ourselves of the surplus capacity of production of the French factories, which had been since the beginning of the war very powerfully equipped and were able to turn out greater quantities than those corresponding to our supply of raw material.

The Allies could deliver the artillery, artillery ammunition, and airplanes if America could deliver the raw and semi-finished materials. America answered that she could and would produce and transport to Europe raw materials and semi-finished products in amounts equivalent to the amounts consumed by Allied factories in manufacturing the completed guns, shell, and airplanes.

The details remained to be worked out. The French high commission submitted statements showing the amounts of each component material consumed in French factories in the production of guns and ammunition of the various calibers. There were to be supplied by America six tons of steel for each 75-millimeter gun, forty tons of steel for each 155-millimeter howitzer, and sixty tons of steel for each 155-millimeter gun, and proper proportionate amounts of necessary materials used in the manufacture of artillery ammunition.

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Thus the program of industrial and economic coöperation between the United States and the Allies took form. It used in the most efficient manner every nook and cranny of every available ship. It utilized to the utmost the surplus manufacturing capacity of France and England. It brought into the war at the earliest moment the resources of America in raw and semi-finished materials. It spanned the period during which America could go forward with her gigantic mobilization of manufacturing power and later convince the Central Empires of the futility of further struggle.

With the program mapped out, reciprocal agreements for supply remained to be made. Orders were promptly placed. The United States ordered from France a total of 5,854 pieces of field and trench artillery of various calibers, of which 3,834 were delivered to the American Expeditionary Forces prior to the armistice. By August, 1917, more artillery ammunition was on order with the French Government than was fired by the American Expeditionary Forces from January 18, 1918, when the first complete American division entered the line, until November 11, 1918, when the end of hostilities was announced to the world. Of the amount ordered, 10,000,000 rounds were delivered before firing ceased.

In aircraft equipment, the French factories also had a surplus capacity, and they delivered to General Pershing up to November 11, 1918, a total of 4,881 finished airplanes.

By the terms of our agreement with the French Government, America obligated herself to supply the raw materials and component parts of the finished products delivered to our forces in France. This agreement America performed twice over. For every ton of raw materials and semi-finished products which America agreed to furnish to France, she furnished two tons. According to French statements, our replacement obligation in raw materials was 350,000 tons. America furnished over 800,000 tons. In exchange for the artillery and artillery ammunition of French manufacture fired by Pershing, America supplied to France, in metals alone, over 700,000 tons of steel, 30,000 tons of pig iron, 5,000 tons of brass and spelter,

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and 50,000 tons of copper. In addition, and for use in the artillery ammunition received from French factories, America manufactured and supplied to France in a finished state all the principal materials used in loading all shell delivered to the American Army. These materials consisted (1) of smokeless powder, used as a propellant to drive the shell from the guns, and (2) picric acid, used as a high-powered detonative to burst over the enemy lines. The French used 12,000 tons of smokeless powder in our shell. America delivered an equivalent amount of finished powder. The French consumed 18,000 tons of picric acid in loading shell for American use. America supplied 18,500 tons.

In exchange for the finished airplanes, America again supplied the raw materials and component parts. For the framework of the French planes driven by American aviators, America furnished 34,500,000 feet of spruce, fir, and cedar, enough to manufacture over 16,000 finished planes; for the propellers, America furnished 7,000,000 feet of mahogany and walnut, enough for 40,000 propellers; 4,000 tons of aluminum, enough for thousands of planes; and dopes for painting airplane wings, and miscellaneous aircraft materials and supplies far in excess of the number of finished planes delivered to General Pershing. Under special contract made in August, 1917, and in addition to the foregoing, America furnished to France all materials for 5,000 finished planes and all parts for 8,500 finished airplane engines, which were to be assembled in France for the American Expeditionary Forces. The engine parts were in forgings and needed only to be machined. For the use of the French Government in machining these engine parts, America built and delivered the necessary equipment and machinery.

Thousands of additional smaller items of all kinds were supplied by the various governments to each other from day to day. No deficiency in the military programs of any of them was permitted to exist if it could be made good by any of the others. All of America's vast contribution to the Allied program of supply was not only produced in America, but it was also

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taken to France in our army transports. From August, 1917, to November 11, 1918, an average of 2,000 tons of American materials for French factories left American ports every day aboard American army transports. Through a submarine-infested ocean, in which the Germans sank over 21,000,000 tons of deadweight shipping, these materials were carried in army transports manned by American crews, and laid down at the doors of French factories.

By February, 1918, General Pershing estimated that 2,000,000 tons of cargo space had been saved by the adoption of this program of international and reciprocal supply, a saving of more tonnage than was then available for the use of the American Expeditionary Forces. The Franco-American commission on explosives estimated a reduction of 75 per cent in cargo space in the shipment of explosives alone.

So the silent drama of international coöperation was carried out. The story of British and American mutual aid during the war is the same story in substance as that of Franco-American coöperation, with changes only in the figures. Economy of shipping was effected. British and French factory capacity was utilized. The vast reservoir of American raw materials and explosives was thrown against the enemy. International cooperation on a scale and in a spirit of cordial, mutual helpfulness such as the world had never dreamed of, helped to equip 2,000,000 American soldiers in France.

And it was done, all of it, without curtailment of the huge stream of material which was flowing from America to the Allies when the United States entered the war. France and England received ever-increasing quantities to the last day. The more than 800,000 tons of replacement materials for artillery, artillery ammunition, and airplanes delivered to America were over and above the millions of tons secured by the Allies for their own use directly from American producers.

It was partly by reason of the adoption of this program and its complete performance that General Pershing, after the armistice, could say:

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During active operations extending from January, 1918, when our first division entered the line, until the close of hostilities on November 11, our troops were supplied with the equipment and ammunition necessary to carry their work to a successful conclusion.

Beyond all this, our Government created, as part of the Interallied program, vast facilities for the manufacture of supplies which England, France, and Italy still required for their own needs and which a comprehensive consideration of the entire program, with particular reference to shipping, showed could be best produced in this country. Factories for the production of immense additional quantities of picric acid, powder, and other materials were built by our War Department to fill the deficiencies in the military programs of our associates in the war.

And beyond and behind all this, America went forward with her own gigantic preparations for the conquest of the dark forces which threatened world civilization. It was this mobilization of her might, almost as much as the leverage of her immediate force, which helped to convince the German general staff of the futility of further resistance and assisted to bring the war to an early end.

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